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The British Grassland Society does not accept responsibility for opinions and statements contained in contributed articles, or in those reproduced from other sources. Nor does it accept responsibility for any statements contained in advertisements included in the Journal.

ADVANCE NOTES ON RESEARCH

The Editor will be pleased to receive advance notes on research results for publication in the Journal. Such notes need to be no more than 200–300 words in length.

BRITISH GRASSLAND SOCIETY

SUMMER MEETING 1961

This Meeting was held in Aberdeen from 10–14 July, the Host Vice-President being Principal M. A. H. Tincker of the North of Scotland College of Agriculture. 185 members attended, of whom 7 were from overseas. The programme for the meeting included visits to the following research institutes, experimental stations and farms: The Rowett Research Institute; Craibstone Estate and the Grasslands Experimental Centre, Muchalls (North of Scotland College of Agriculture); Glensaugh Farm, Fettercairn (Hill Farming Research Organization); Nether Mains, Torphine (Mr. Edwin Booth); Troup Hill Grazings, Pennan (Mr. A. Watt Taylor); Kininvie, Craigellachie (Mr. A. G. Thomson); Tillycorthie Estate, Udny (University of Aberdeen), and Westertown, Rothienorman (Mr. Maitland Mackie Jun.).

The Annual General Meeting of the Society was held on 11 July, when the following Officers were elected: President-Elect Mr. H. J. Gill; Host Vice-President 1962, Earl de la Warr; New Committee Members, Mr. W. R. Trehane, Mr. A. R. Wannop and Mr. Glyn Williams.

The Annual Dinner of the Society, held in the Elphinstone Hall, King's College, was well attended.

WINTER MEETING 1961

The Winter Meeting will be held on Friday 8 December in the hall of the Federation of British Industries, 21 Tothill Street, Westminster. The theme for the meeting is to be, "Recent developments in fodder conservation".

SUMMER MEETING 1962

The 1962 Summer Meeting of the Society will be centred on Chichester. Farms and experimental centres in Surrey, Sussex and Hampshire will be visited.

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THE PRODUCTION AND UTILIZATION OF WINTER GRASS AT VARIOUS CENTRES IN ENGLAND AND WALES, 1954–60

I. Management for herbage production

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and
G. Pearson Hughes
National Agricultural Advisory Service

The effects of management on the production of winter grass were studied at 47 sites in England and Wales from 1954 to 1958.

Cocksfoot swards provided better grazing during December and January than perennial ryegrass. The best treatment for winter-grass production from cocksfoot swards was to rest from mid-August, giving an application of 52 lb. of nitrogen per acre at this time.

Perennial ryegrass swards produced relatively high yields if rested from early September, but the herbage should be grazed before the end of November because of the risk of it rotting.

Cocksfoot herbage in normal swards lost more weight from December to January than cocksfoot sown in wide drills.

Local factors, such as aspect, altitude and sward vigour, were generally more important than latitude in determining level of yield in December, but there were greater losses of dry matter from December to January in the north than in the south.

INTRODUCTION

Interest in the provision of grazing during the late autumn through into the actual winter months has been stimulated by work at a number of research centres. In mid-Wales during the 1930's Griffith and Hutton (7, 8) used timothy sown in wide drills for the home wintering of ewe hoggs on the hills, and considered the system to be of value in comparison with other means of wintering; Davies and Fagan (4) studied the effects of time of resting in the late summer and autumn on the botanical composition of a general-purpose sward and also estimated subsequent yields and quality of herbage during the winter.

Hughes (9) presented and discussed experimental results on the production of winter grass, and its utilization by beef stores on heavy clay soils in the Midlands. These investigations indicated that the growing of grass and its use in winter were possible under certain conditions, and that some part at least of the winter-feed requirements of grazing stock could be provided by grass. It was considered desirable to test these results under a wide range of environmental conditions, and this was undertaken as a joint project by The Grassland Institute and officers of the National Agricultural Advisory Service, with the co-operation of farmers in different parts of the country. This paper deals with the production of herbage in these national trials.

TREATMENTS AND SAMPLING

Swards were not sown specifically for this investigation, but were chosen from existing fields on commercial and experimental husbandry farms throughout England and Wales. The distribution of these centres is shown in Fig. 1. Most of the swards were cocksfoot-dominant leys which had either been sown with a cocksfoot/white-clover mixture, or were of a general-purpose type in which the management had encouraged the development of cocksfoot. At some centres the cocksfoot had been sown in wide drills, either by itself, for

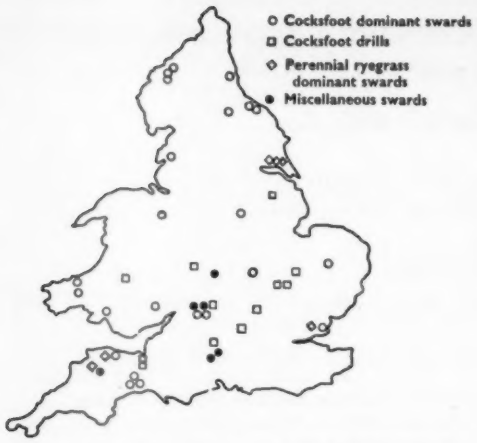

Fig. 1. The distribution of winter grass trials 1954–58.

seed production, or in alternate drills with lucerne. In a few swards sown to general-purpose mixtures perennial ryegrass was dominant at the time of investigation; there were also a few miscellaneous swards.

The influence of time of resting in the late summer and early autumn on the provision of grazing in December and January was studied by resting swards from two different dates at each centre. Dates of resting ranged from mid-July to mid-September.

Three levels of nitrogenous fertilizer, 0, 52 and 104 lb. nitrogen per acre, were applied to each field when it was rested.

All treatments were sampled for dry-matter yield and crude-protein content in the first half of December and again in the first half of January (10).

DISCUSSION OF RESULTS

The average yields of dry matter per acre in December for each year are given in Table 1. The resting dates have been grouped into fortnightly periods from mid-July to the end of September. The yields of the early-rested swards in 1955–6 were considerably lower than those obtained in other years, while those of 1954–5 were generally higher. Yields decreased progressively with later resting dates, particularly after the end of August. The application of nitrogen increased yields, but these increases were much smaller when resting and application were both delayed until September. The average yields obtained in January followed the same pattern as those of December, but they were generally lower.

Table 2 shows the average yields of each sward type in the experiment. The December yields and the responses to resting dates and fertilizer treatment were similar on both cocksfoot-dominant swards and in cocksfoot drills. Between December and January, however, there was a greater loss of dry matter on the swards. Gardner (6) found that in Scotland also broadcast stands of cocksfoot had a greater loss of herbage during winter than wide drills. The perennial ryegrass-dominant swards produced their highest yields when rested from mid-August. The highest yields of the miscellaneous swards were well below those of the other groups.

Crude-protein content varied widely, but the values given in Table 3 for cocksfoot swards are representative of the other sward types. The application of nitrogen increased the crude-protein content, and high values were frequently obtained on swards rested after the beginning of September. Within each treatment there was little change in the crude-protein content from December to January.

The data from this experiment confirmed that the production of winter grass, obtained at experimental centres, could also be achieved on commercial farms under a wide range of

TABLE 3. Range of percentage of crude protein in cocksfoot-dominant swards during December and January

Nitrogen treatment lb. per acre	Date of resting				
	Second half July	First half August	Second half August	First half September	Second half September
0	8–12	12–18	12–16	11–26	10–23
52	13–14	13–22	13–16	14–29	12–21
104	13–14	13–24	14–20	20–28	18–27

TABLE 1. Influence of resting date and fertilizer application on the average dry-matter yield of herbage during December and January

Dry matter in lb. per acre

Resting date / Fertilizer treatment†		Second half July				First half August				Second half August				First half September				Second half September			
			0	52	104		0	52	104		0	52	104		0	52	104		0	52	104
1954/5	December	(2)*	1480	2190	2580	(2)	1680	2420	2820	(4)	1240	1960	1950	(4)	700	1130	1560		—	—	—
	January		—	—	—		—	—	—	(2)	1000	1300	1800		—	—	—		—	—	—
1955/6	December		—	—	—	(5)	730	1120	1280	(3)	570	1040	1300	(5)	460	610	990	(4)	220	400	610
	January		—	—	—	(4)	760	940	1140	(3)	480	800	1100	(4)	400	490	850	(4)	110	270	500
1956/7	December	(1)	1560	1870	2280	(9)	1030	1580	1840	(6)	740	1660	2120	(8)	280	500	780	(5)	310	620	970
	January	(1)	1120	1520	1370	(8)	910	1420	1570	(7)	640	1350	1770	(8)	260	500	730	(6)	280	570	820
1957/8	December		—	—	—	(10)	930	1730	2100		—	—	—	(9)	370	760	940	(1)	40	170	230
	January		—	—	—	(9)	790	1480	1760		—	—	—	(8)	260	570	740	(1)	10	50	110

*Figures in brackets denote number of sites.
†Lb. of nitrogen per acre at time of resting.

TABLE 2. Influence of resting date and fertilizer treatment on the average dry-matter yield of various sward types

Dry matter in lb. per acre

Resting date / Fertilizer treatment†		Second half July				First half August				Second half August				First half September				Second half September			
			0	52	104		0	52	104		0	52	104		0	52	104		0	52	104
Cocksfoot-dominant swards	December	(1)	1560	1870	2280	(13)	900	1660	2020	(6)	510	1560	1820	(12)	330	680	950	(5)	160	400	650
	January	(1)	1120	1520	1370	(11)	640	1270	1510	(7)	600	1170	1570	(11)	260	520	720	(6)	190	440	620
Cocksfoot drills	December	(2)	1480	2190	2580	(6)	1000	1560	1820	(4)	680	1140	1640	(5)	210	460	600	(3)	210	350	620
	January		—	—	—	(5)	940	1450	1650	(3)	650	1040	1580	(4)	110	350	550	(3)	150	240	460
Perennial-ryegrass-dominant swards	December		—	—	—	(3)	1140	1800	2050	(2)	2180	3010	3080	(4)	850	1220	1720	(1)	790	1580	2100
	January		—	—	—	(2)	1340	1840	2330	(1)	1110	2390	2820	(2)	780	910	1410	(1)	480	1270	1940
Miscellaneous swards	December		—	—	—	(4)	1120	1380	1550	(1)	930	950	810	(5)	460	620	930	(1)	260	260	330
	January		—	—	—	(3)	1000	1180	1160	(1)	620	710	740	(3)	380	540	710	(1)	70	80	90

environment. Moreover, the grass was obtained on swards already in existence, and no special leys were sown. Weather in the early autumn had a marked effect on the quantity of winter grass available. In 1955/6, when August and September were very dry, there was only a small response to the application of nitrogenous fertilizer, and low yields were obtained (Table 1). However, in the remaining three seasons there was adequate rainfall and growth was satisfactory.

The average effect of the autumn treatments is shown in Fig. 2. In December the highest yields were obtained from the swards rested

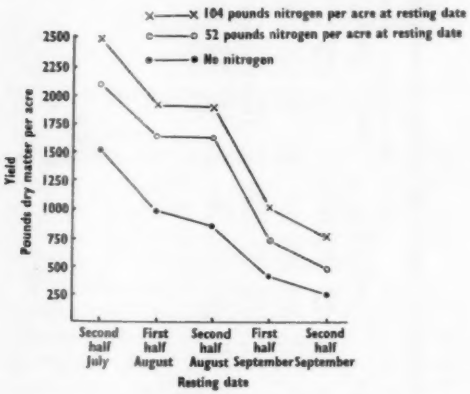

Fig. 2. Influence of date of resting on the average yield of winter grass in December.

from mid- to late-July. However, this herbage was generally too mature, had an excessive amount of "burn" and had in many cases rotted badly. Where nitrogen was applied, swards rested either from the first or the second half of August produced similar December yields. Those rested later were greener in the winter and contained better herbage, but the yields were considerably lower. Resting from the second half of August produced the best compromise between yield and quality.

Since 52 lb. of nitrogen per acre gave a better return per unit of nitrogen than 104 lb. (15 and 10 lb. of herbage per lb. of applied nitrogen, respectively, Fig. 2) the optimum treatment appeared to be resting from the second half of August and applying 52 lb. of nitrogen per acre at that time. The average yield produced in December by this treatment was 1600 lb. of dry matter per acre. In Scotland, Gardner and Hunt (5), and Corbett (3), also reported that 52 lb. of nitrogen per acre was the optimum for winter-grass production, but they concluded that under their conditions the swards should be rested from the first half of August.

The yields from cocksfoot-dominant swards followed the general pattern outlined above. The best time to rest them and apply nitrogen was in the second half of August (Table 2). The highest yields from perennial ryegrass were obtained by resting at the end of August, but relatively high yields were also obtained from swards rested in September. The earliest-rested perennial ryegrass swards had rotted badly by December, resulting in lower yields. In December all the ryegrass herbage contained excessive "burn" and was too badly rotted to be of real value for feeding. Corbett (2) also obtained high herbage losses in perennial ryegrass because of rotting, with consequent poor utilization during winter. The above treatment may prove detrimental to the persistency of perennial ryegrass, as noted by Baker (1). The general impression

TABLE 4. Dry-matter yields of swards rested from early-mid August (1957)

Nitrogen treatment lb. per acre	Date	Cocksfoot swards North (3 centres)	Cocksfoot swards Midlands (3 centres)	Cocksfoot/lucerne alternate drills Midlands (2 centres)
0	December	830	740	1200
	January	610	720	1140
52	December	1650	1790	1800
	January	1260	1470	1820
104	December	2110	2240	2110
	January	1590	1870	2060

was that the best results from the ryegrass-dominant swards were obtained by resting from September, but because of the deterioration in the quality of the grass in early winter the resultant growth should be grazed before the end of November.

On both cocksfoot and perennial ryegrass swards losses of dry matter occurred between December and January and were most severe in the north of England; losses were less on cocksfoot in wide drills. Table 4 shows a comparison made during one season between three cocksfoot swards in northern England, three similar swards in the Midlands, and two cocksfoot stands in alternate drills with lucerne, also in the Midlands. In December average yields differed little, but between December and January the northern centres lost far more herbage, particularly on the high-nitrogen treatments. By January cocksfoot in wide drills had lost less herbage than the normal swards. The denser herbage of cocksfoot swards appeared to be more badly affected by fungal infection, particularly in southern England, and in one or two instances severe infestations of leaf fleck (*Mastigosporium* spp.) made the grass unpalatable. The comparative immunity of the wide drills was probably due to the more erect habit of growth of the herbage, and the better circulation of air between the drills.

Such factors as aspect, altitude and general vigour of the sward appeared to be more important in terms of winter-grass production than latitude, although, as indicated above, there were greater losses of dry matter in the north from December to January.

ACKNOWLEDGEMENTS

Our sincere thanks are due to all the farmers who co-operated so wholeheartedly in these trials and who provided the necessary facilities. We also wish to acknowledge most gratefully the valuable assistance and co-operation of many Grassland- and Advisory-Officers of the National Agricultural Advisory Service.

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THE PROBLEM OF *NARDUS* AND ITS PRODUCTIVITY IN RELATION TO SHEEP GRAZING AT MOOR HOUSE, WESTMORLAND

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Attention is drawn to the increase of the unpalatable and unproductive grass, *Nardus stricta*, on hill grazings. This increase is considered to be related to a decline in soil fertility, which is being hastened by present-day management.

An experiment to measure the production of a typical *Nardus*-dominated sward at 1700 feet O.D. on the northern Pennines is described. The results show that there was no increase in dry matter during the growing season. There was however an increase in some mineral elements. A manurial treatment showed poor response, but when the sward was cut and the herbage removed in spring, subsequent manuring gave spectacular yields.

INTRODUCTION

Variability in the composition of the vegetation is the keynote of many problems of hill grazing. As has been pointed out by Hunter (1) this can be an asset, especially when all-year-round grazing is practised. However, variability implies the presence of some undesirable plant species. Whereas bracken is the problem lower down the hill, it is Mat-grass (*Nardus stricta*) that concerns us on the higher grasslands. The presence of this grass indicates soil of poor fertility, and the fertility of our hills is annually deteriorating at an ever-increasing, though unspectacular, rate. It is significant that the acreage of *Nardus*-dominated grassland is spreading, and that the increase is at the expense of the better swards. There is little doubt that human management is to blame.

Nardus is unpalatable to most stock, and nutritionally it is poor in mineral elements. It is said (3) to be eaten in the spring of the year, when its nutritive value is highest. However, on the higher grasslands, under present-day grazing management, it is largely untouched throughout the year; this was not always the case, as has been shown by Roberts (2) and others. The grass was previously kept in check, firstly by cattle grazing on the summer shielings, and later, during the days of the increase in hill sheep flocks, by the wintering of wethers on the hill. Roberts mentions the beneficial action of these older sheep not only in eating the grass during the winter but in uprooting whole plants, drifts of which could be seen, only fifty years ago, filling the dykes and collecting against stone walls. The pattern of grazing has, however, changed, due mainly to consumer demand for lamb and the smaller joints of mutton. Nowadays most fells are grazed throughout the year and, what is more, it is the ewe and her lamb, the animals that make the most demand for minerals, that are doing the grazing. This type of grazing naturally results in the selection of the more nutritious species to an even greater extent, and, of course, to a greater avoidance of *Nardus*. If untouched, *Nardus* not only spreads into the over-grazed neighbouring grassland but itself becomes an unhealthy plant; it layers the ground surface between tussocks with dead fibrous leaves that are slow to decay and stifle the growth of other species.

Similarity between hill grazings exists only in general terms, and the following is a brief account of part of the Moor House Nature Reserve on which the present investigation was carried out. The Reserve covers 10,000 acres of common land on the northern Pennines. The common rights are unrestricted and on the greater part of the Reserve the only grazing animals are the sheep, which, contrary to

general practice, are removed to lowland pastures for the winter. The breed is the Swaledale, a thrifty animal that has been steadily increasing in popularity in north-west England. The vegetation is mostly heather covering deep peat, but on the mineral soils small areas of grassland occur. These oases of grassland are found at their best on the limestone outcrops and they provide a nutritious sward predominantly of Sheep's fescue (*Festuca ovina*). They may be described as *Festuca/Agrostis* swards. Certain of the alluvial grasslands are also *Festuca/Agrostis*-dominated and they too are much favoured by the sheep. However, the majority of the areas are poor and unproductive, and they contain varying amounts of *Nardus*. The land rises from 1600 feet to 2780 feet above sea level, whilst the average annual rainfall at 1800 feet is about 75 inches.

EXPERIMENTS

Measurements on the grassland at Moor House have been concerned with productivity as well as with the effects of sheep grazing. One pilot experiment studied the productivity of *Nardus* dominating an alluvial grassland area by the river Tees. The site, at 1700 feet O.D., map reference NY(35)772330, is an isolated community, bounded on one side by heather moor and on the other by the river. The soil, a dark sandy peaty material, 12 inches deep, overlies an impervious pebble bed. It gave the following results on analysis: pH 5, CaO 0·08%, P_2O_5 0·002%, K_2O 0·06% and N 0·28%. Productivity was estimated by taking samples of the herbage with hand shears to 0·75 in. from ground level and obtaining the weights of dry matter and some plant constituents. The chemical analyses of the crop included determinations of ash, calcium, phosphorus, potassium, nitrogen, silica (as SiO_2) and normal acid fibre, and were made by the Chemical Service of Merlewood Research Station, using standard methods. A sheep-proof enclosure was erected and a set of twice-replicated plots, each of 96 sq. ft., was laid out, leaving a corresponding series open to grazing nearby.

The objects of the experiment were:

(1) To measure the production of herbage in one season, by estimating the difference in yield between the autumn crop within the enclosure and the crop taken in March, before growth had begun;

(2) To measure the effect of a fertilizer treatment. Ground limestone was applied to a set of plots early in the year at a rate of 36 cwt. per acre. This was followed by a compound fertilizer containing 5·5% N, 12·5% P and 12·5% K, and then by a top dressing of nitro-chalk (15·5% N), both at 3 cwt./acre. Measurements were to be obtained from the herbage within the enclosure and from plots open to grazing.

(3) To measure the effect of cutting as a treatment. The plots that had been cropped in March for the initial yields (measurement No. (1)) were allowed to recover and samples were taken from the new growth at the end of the season. Half these plots received the same manurial treatment of lime and fertilizer as that given in measurement No. (2).

RESULTS

(1) *Annual production*

The dry-matter yield of the autumn harvest proved to be 9% less than the March crop. However, the production of ash, nitrogen, phosphorus, potassium and calcium was greater. The dry matter at the beginning of the season was increased by greater fibre weight and slightly more silica. The actual amounts

TABLE 1. Yields of dry matter and some plant constituents and their percentage contents

	Yield in lb. per acre on dry-weight basis							
	D.M.	Ash	SiO_2	N	P	K	Ca	Normal acid fibre
Beginning of season	3664	144	8	43	4	12	2	1528
End of season	3340	195	7	60	7	54	10	1405
	Percentage content on dry-weight basis							
Beginning of season		3·9	2·2	1·2	1·1	3·3	0·6	41·7
End of season		5·6	1·9	1·7	1·8	16·2	2·7	42·1

TABLE 2. The production of mineral elements and some plant constituents from two alluvial grasslands at Moor House, in lb./acre

	D.M.	Ash	SiO_2	N	P	K	Ca	Normal acid fibre
Nardus	−324	51	−1	17	3	42	8	−122
Festuca/Agrostis	2213	124	3	43	3	39	10	882

and the percentage contents are shown in Table 1.

These figures show that, even if the sward is producing nothing in terms of dry matter, there is an increment in mineral yield, which according to Thomas and Fairbairn (2) and other workers takes place early in the growing season.

Table 2 compares the production of this *Nardus* vegetation with a *Festuca/Agrostis* sward some 400 yards away, also on alluvium. Sampling took place at the same time, late in August.

In view of the difference in dry-matter production it is perhaps surprising that the difference in calcium was not greater: the figures for nitrogen and ash do, however, demonstrate the superiority of the *Festuca/Agrostis*.

(2) *The effect of a fertilizer treatment*

The treatment showed no marked effect on the appearance of the vegetation, but on analysis there were increases in dry-matter production by the end of the season. Calcium yield was increased by 50% and the dry matter by 1000 lb./acre over the unfertilized crop. This increase compares with 2300 lb. obtained with the same manurial dressing on the *Festuca/Agrostis* sward. There was no difference in dry matter on the area outside, open to grazing, but once more the nutrient contents were raised by fertilizing.

The erecting of the enclosure undoubtedly attracted sheep, and the unfenced plots probably received more attention than they would otherwise have had.

(3) *Cutting as a treatment*

To cut a crop to 0·75 in. from ground level is a severe treatment, especially with *Nardus*, normally a slow-growing plant. Recovery took time and even in July, four months after the cutting, there was little vegetation on some of these plots, as can be seen from the following figures:

Enclosed, control	21%	bare ground
Enclosed, fertilized	8%	„ „
Open grazed, control	42%	„ „
Open grazed, fertilized	19%	„ „

By August, however, the fertilized plots within the enclosure had made spectacular growth, particularly of *Agrostis* spp., with *Anthoxanthum odoratum* and *Luzula multiflora* combining to crowd out the slowly-shooting *Nardus*. Nearby the controls were also recovering, though in their case the sward

TABLE 3. The percentage content of elements in treated herbage on a dry-weight basis

	N	P	K	Ca
Enclosed, control	1·7	1·8	16·2	2·7
Enclosed, fertilized	1·8	2·2	16·8	7·3
Open grazed, control	1·7	0·8	14·4	1·4
Open grazed, fertilized	2·0	1·4	19·6	5·5

TABLE 4. The regrowth from March-cropped *Nardus* sward. Production, in lb./acre dry weights, of herbage harvested in late August

	D.M.	Ash	SiO_2	N	P	K	Ca	Normal acid fibre
Enclosed, control	2066	120	4	40	3	34	5	453
Enclosed, fertilized	3303	224	8	68	5	62	13	647
Open grazed, control	552	30	1	12	1	9	1	235
Open grazed, fertilized	1176	89	2	29	3	21	5	540

remained clearly *Nardus*-dominant. The plots open to grazing did not recover to the same extent, whether fertilized or not. The results are shown in Table 4.

CONCLUSIONS

Although this was an exploratory investigation and greater replication would have been desirable on a sward as variable as this, there is no reason to doubt the evidence that the productivity of the alluvial *Nardus* is very low. Though there is no annual dry-matter increment there appears to be an increase in most plant constituents by the end of the growing season. The effect of applying fertilizers was to increase the production, but there is no suggestion that this is lasting nor was the response great. Cutting and removing a crop in the early part of the year resulted in impressive regrowth, especially when grazing was prevented and fertilizers were applied. Again, there is no indication that the improvement would be other than very temporary. Reversion to a *Nardus* sward was rapidly taking place on all plots in the season following the experiment.

It is apparent that the type of grazing animal on these fells is in no way assisting to control the *Nardus* communities. However, the rest that the more palatable swards are receiving during the winter is in a small way preventing a too rapid deterioration in fertility and the spread of *Nardus*. Improvement to a *Nardus* sward, once it has reached the state of this area under investigation, is unlikely to be lasting and will probably always be an uneconomic enterprise. It is therefore all the more important that hill grasslands should be managed to prevent them reaching such a level. It is the swards with *Nardus* present, but not yet dominant, that should receive immediate attention, by controlling the grazing and by manurial treatment where possible.

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BENEFIT OF LEYS—STRUCTURAL IMPROVEMENT OR NITROGEN RESERVES

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Although it has been widely established that increased crop yields follow leys sown on arable land, the relative importance of the many causative factors which may be involved is obscure. An attempt has been made to evaluate the influence of 3- to 4-year leys on the organic matter in an arable soil and to distinguish also the relative importance of the resultant change in moisture-holding capacity, crumb stability and the nitrogen status of the soil as factors in the yield of winter wheat.

An increase of about 4 tons per acre in total soil organic matter was recorded after 3 years under grazed swards. Moisture-holding capacity increased by an amount equivalent to the evapo-transpiration loss from a full plant cover on one summer day. An increase in crumb stability was largely confined to the top inch of soil, which is effectively buried when leys are ploughed.

The influence of variation in soil nitrogen status and in crumb stability on the yield of winter wheat after leys was examined by multiple regression analysis of data obtained over a number of years from field experiments. After allowing for the effect of variation in the nitrogen status of the soil, the influence of variation in crumb stability was insignificant. Conversely variation in the nitrogen status of soils, sampled under leys before ploughing, was closely correlated ($r = +0{\cdot}93^{***}$) with wheat yield.

INTRODUCTION

The effect on soil productivity of sowing land to temporary grass can be considered in the context of two distinct systems of farming. On the one hand is ley farming—which is essentially grassland farming with the judicious use of the plough. On the other is alternate husbandry—or arable farming with a grassland break of several years' duration within each cycle of the rotation.

Ley farming is a comparatively modern practice. Alternate husbandry dates back to the bush fallow: in this country to the Celtic 'wild field' system. There is another important distinction between these two conceptions of 'temporary grass'. Grass farming with a plough is a highly specialized form of agriculture; alternate husbandry is a system leading to mixed farming with diversification of farm enterprises. From the point of view of soil technology these two farming systems present very different problems. The discussion which follows relates to the practice of alternate husbandry with 3½-year leys in an arable rotation.

To say that the relationship between the grass phase and subsequent arable cropping is complex would be commonplace. As Ashby (1) points out, the use of leys may involve the whole enterprise structure of a farm. But considered solely as an element in arable cropping the advocacy of the ley relies upon the provision by the grassland phase of some return which is either not available, or procurable only at greater cost, from other sources. The major nutrients, nitrogen, phosphate and potash, can be purchased in various forms, and in so far as the ley affects the supply of such nutrients its residual effect on fertility may be costed with reasonable accuracy. In the same way possible control of weeds, pests or diseases by the ley may be equated with the cost and efficiency of chemical control.

FIELD EXPERIMENTATION

Organic matter

Changes in the organic-matter content and in the physical condition of soils under leys present a more difficult problem in crop

*Paper read at the joint meeting of the British Grassland Society and the British Society of Soil Science in London on 8 December 1960.

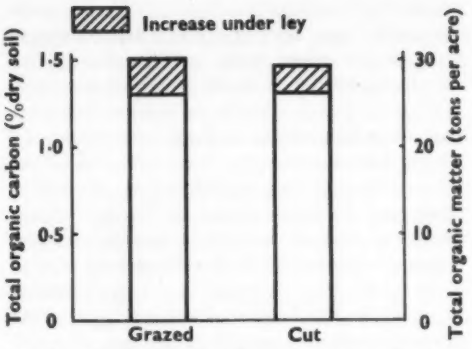

Fig. 1. The increase in soil organic matter after three years under grazed and cut leys. All forms of organic material, including roots, present in the top 6 in. soil.

accountancy. As shown in Fig. 1, after three years' ley, the organic matter in an acre of arable soil at Hurley increased by about 4 tons. Over half this increase was in the form of fragments of fibrous organic matter, mainly grass roots.

Water supply

The increase in the amount of water held in the same soil is shown in Fig. 2. A water tension of 75 cm. corresponds approximately to field capacity for this soil and only a part of the water held at this tension will be available to crops; some of the increase shown in Fig. 2 will still be held in the soil at wilting point. It is considered that the increase in soil water available to crops, after a period of 3 to 4 years under grass, amounts to about 10 tons per acre, or one day's evapo-transpiration loss for each cycle of wetting and drying.

Crumb stability

Current methods of assessing structure in soils are not entirely satisfactory. There is also little quantitative information on the physical edaphic requirements of most crops. It is perhaps by the ease with which a tilth can be produced that the apparent influence of leys on soil structure is most frequently appraised. As Russell (15) pointed out, the qualities of 'tilth' are many and the meaning of 'good tilth' is difficult to define. A statement by Bradfield (2) distinguished two distinct effects of grassland: "Soils may be granulated by the action of frosts or by wetting and drying. In many cases there seems to be little difference superficially between the granules resulting from these purely physical processes and those produced from a grass sod. The grass seems to do something which makes the granules more stable."

Although leys may aid the granulation of many soils, the weathering of the furrow slice, and the right kind of cultivation sequence,

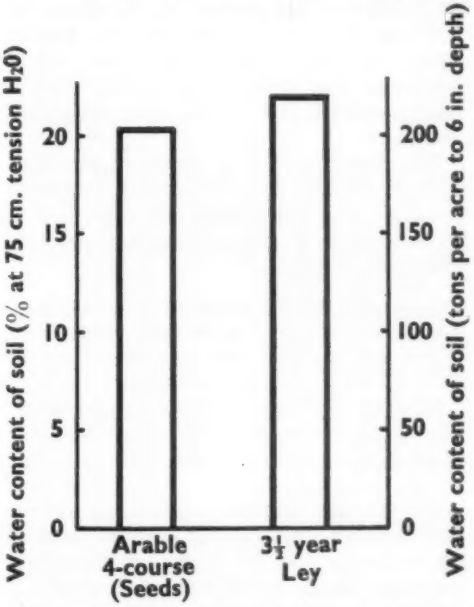

Fig. 2. Water-holding capacity of soil after leys and arable.

commonly provide a structure suitable for the production of arable crops. The effect of the ley in stabilizing soil crumbs is therefore often considered to be of greater importance than any influence it may have on granulation. Upon the stability of the crumbs will depend the persistence of the structure.

The crumb stability of a sandy loam arable soil at Hurley as determined by wet sieving was more than doubled after three years under ley, *vide* the following figures:

	Water-stable aggregates >0·5 mm. g./100 g. dry soil	
	Experiment H9	Experiment H16
6 months after sowing leys	2·8	2·6
3½ years „ „ „	7·3	7·3
Increase	4·5±0·3	4·7±0·5

These increases are each mean values derived from a number of leys differing in species composition, levels of nitrogen manuring and systems of utilization. Such management practices influence the size of the increase in the stability of soil crumbs but the effects are not large (Clement and Williams (3)). Results agree with those reported by Low (10) in suggesting that stability of crumbs after 3 years under ley is much less than under old grassland.

The discussion has so far been concerned with the analysis of soils sampled to plough depth (6 in.). An examination of the soil profile beneath a series of 3-year leys gave the following results:

Horizon cm.	Water-stable aggregates >0·5 mm. g./100 g. dry soil
0–2	20·1±0·5
2–4	7·0±0·2
4–6	5·8±0·1
6–8	5·4±0·5
8–10	4·9±0·5
10–12	4·7±0·4

By far the greatest increase in crumb stability after 3 years under grass occurred in the surface 2 cm. of this arable soil. Ploughing the sward largely buried this top layer of soil and brought to the surface material little affected by the period under ley (Clement and Williams (4)).

Nitrogen supply

A period under grassland has been found to influence greatly the mineralization of nitrogen in soils incubated under standard conditions in the laboratory. Richardson (14) examined this subject in some detail and recognized the importance of the increase in the nitrogen content of soils which seems almost invariably to occur when arable soils are held under grass. The manuring, legume content and method of utilizing a ley can cause wide variation in the amount of nitrogen mineralized when soils are incubated for 20 days at 30°C (Grassland Research Inst. (6)). A close correlation has been observed between these values and the uptake of nitrogen by winter wheat sown after leys. The size of the increase in nitrogen available from the soil is illustrated by some results at Hurley: wheat after the seeds break of an arable 4-course rotation removed 50 lb. of nitrogen per acre in grain and straw, whereas the corresponding value after three years of grazed leys varied from about 80 to over 100 lb. per acre.

Soil structure, nitrogen status and wheat yield

Under temperate conditions evidence of reduced yields resulting from deterioration in the structure of freely-drained soils is both fragmentary and inconclusive. But the suspicion remains that such effects may often occur and are not diagnosed in the absence of recognized symptoms.

Comparing soil structure and the growth of wheat in plots under 2- and 4-course rotations at the Waite Institute, McIntyre (12) concluded that a soil crust produced by heavy rainfall, coupled with a low degree of crumb stability, reduced germination. Although germination and subsequent yields were apparently related, it was emphasized that other important factors, such as nitrogen supply, also varied between the plots. McIntyre considered that if, under the conditions of the experiment, a good establishment was obtained, high yields could nonetheless result on the poorly-structured soils. Only in certain phases of development, and in certain years, may poor structure limit growth.

Although it seems reasonable to suppose that variation in crumb stability must in some way influence the edaphic physical environment of a crop, relatively few attempts have been made to assess the effect in terms of yield, and although some authors (Van Bavel and Schaller (17)) have reported close correlation between crop yield and the results of aggregate analysis, McHenry *et al.* (11) failed to find this relationship in soils that had been under grassland for periods varying from one

to nine years. Variation in the initial crumb structure and stability of soils, and in the level of other limiting factors, may explain such conflicting results. Even when a correlation between crumb stability, or some other characteristic of soil structure, and crop yield is observed within a particular experiment, this alone cannot be accepted as evidence of a direct causal relationship: it is necessary always to consider related changes in organic matter and in the nutrient status of the soil.

Ferrari (5) with potatoes and Kuipers (9) with sugar-beet investigated the relationship between many soil factors and yield, using multiple regression analyses. When nutrient components of the crop environment were held constant, variation due to soil structure was slight.

Replicate blocks of grass plots at Hurley have been ploughed and sown to Hybrid 46 winter wheat each autumn from 1953 to 1959. The wide range of ley treatments involved in two of these experiments, H.9 and H.16, provide a basis for the regression of wheat yield on the varying levels of crumb stability and mineralizable nitrogen in the soil after $3\frac{1}{2}$ years under ley. In the diagrams and equations which follow, X_1=parts per million mineral nitrogen in soil incubated for 20 days at 30°C, X_2=water-stable aggregates >0·5 mm. g. per 100 g. dry soil to 6 in. depth, and Y=yield of grain at 14% moisture, cwt./acre.

The two diagrams in Fig. 3, constructed from the multiple regression formulae, do not show in either experiment any appreciable variation in wheat yield after leys which can be related to variation in crumb stability. Conversely a relationship between yield and the nitrogen status of the soil is clearly defined.

In the following table the regression formulae and the standard errors of the estimates of grain yield are compared with and without a component for variation in crumb stability:

Regression formulae	S.E. of estimate of Y
Experiment H.9	
$Y=0{\cdot}46X_1+12{\cdot}7$	$\pm 2{\cdot}8$ cwt. per acre
$Y=0{\cdot}45X_1+0{\cdot}12X_2+8{\cdot}4$	$\pm 2{\cdot}9$ cwt. per acre
Experiment H.16	
$Y=0{\cdot}54X_1+9{\cdot}5$	$\pm 3{\cdot}4$ cwt. per acre
$Y=0{\cdot}56X_1-1{\cdot}51X_2+19{\cdot}0$	$\pm 3{\cdot}4$ cwt. per acre

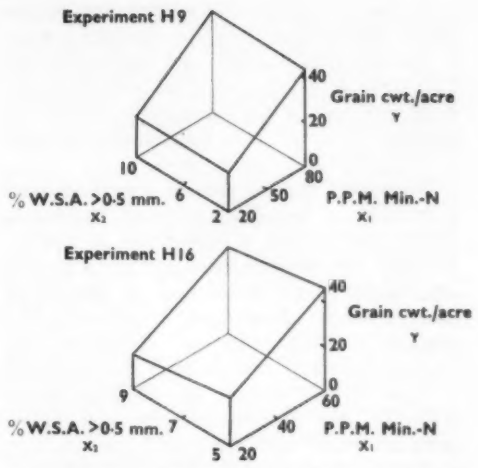

Fig. 3. Relationship after leys between the crumb stability and nitrogen status of the soil and the yield of winter wheat.

It is apparent that the inclusion of a factor for variation in the structure of soil, as measured by crumb stability immediately before ploughing, did not increase the accuracy of prediction of wheat yield. In experiments H.9 and H.16, respectively, 86 and 77% of the variation in grain yield following the different leys was accounted for by a direct regression on the level of mineral nitrogen in the soil after incubation.

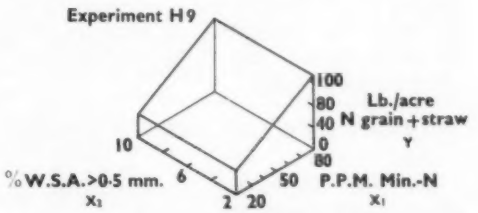

Fig. 4. Relationship after leys between the crumb stability and nitrogen status of the soil and the yield of N in grain and straw of winter wheat.

Fig. 4 illustrates a similar multiple regression of nitrogen harvested in wheat grain plus straw on both water-stable aggregation and nitrogen status of soils using all ley treatments of experiment H.9. When the direct effect of soil nitrogen status is removed, the regression

coefficient of water-stable aggregation immediately before ploughing on nitrogen uptake by the wheat is negative and not significant. The error associated with the estimation of wheat nitrogen is not appreciably reduced by introducing variation in water-stable aggregation into the regression analysis.

The results of these statistical analyses pose a number of problems in their agronomic interpretation. First, a high degree of association can only be considered to reflect a general relationship to the extent that the breadth of observation is unrestricted. Experiment H.9 covered a wide range of utilization and nitrogen manurial practices and H.16 included a reasonable spectrum of different sward types. In other respects the observed regressions are greatly restricted: only one soil, only 3 or 4 seasons, and the deliberate blanketing of phosphate and potash effects.

Second, the conclusion that variation in physical conditions of the soil was of no significance as a factor in the yield of a wheat crop after leys depends on the validity of two premises:

(a) Water-stable aggregation is a measure of variation in the physical condition of the soil following diverse leys;

(b) Mineralized nitrogen is measured independently of variation in crumb stability and physical condition in the field.

It was thought desirable therefore to attempt a more direct experimental verification of the hypothesis that the increases in crumb stability of the Hurley soil after ley had no significant effect on wheat yield.

Effect of synthetic soil conditioner on wheat yield

Synthetic conditioners were selected by Hedrich and Mowry (8):

(a) to promote crumb stability when applied to the soil in relatively small quantities and

(b) to resist decomposition by soil micro-organisms.

Thus the addition of Krilium (a synthetic polyelectrolyte) to an arable soil, although it will increase water-stable aggregation, will not directly contribute to the nutritionally reactive carbon and nitrogen. This suggested a simple method for testing the hypothesis that crumb instability was not limiting wheat yield.

A small experiment, consisting of 3 blocks of 2-treatments plots, one with and one without the addition of a soil conditioner, was laid down on the same field as experiment H.9. Plots were 8 ft. long by 2 ft. wide and on appropriate plots 2 lb. of the Merloam formulation of Krilium were incorporated to a depth of 6 in. Because of the cloddy nature of the soil a coarse tilth was obtained and this persisted on the Merloam-treated plots throughout the summer. Following cultivation in autumn, however, a good tilth was obtained on all plots, and the Merloam-treated plots did appear more friable. Samples were taken for aggregate analysis and all plots were dressed with the equivalent of 6 cwt. per acre of a complete fertilizer (12% N, 12% P_2O_5, 15% K_2O) and sown in 7 in. drills to Hybrid 46 winter wheat.

The results of aggregate analysis of soil from the treated and untreated plots at the time of sowing and at harvest are summarized in Fig. 5.

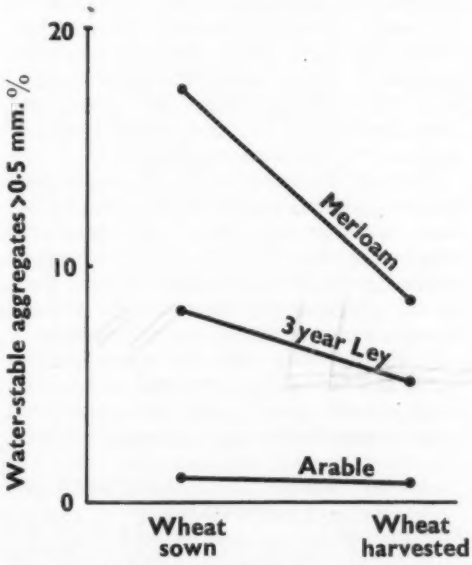

Fig. 5. The effect of 3-year leys and a synthetic soil conditioner on the crumb stability of an arable soil.

By autumn of 1953 the spring application of the polyelectrolyte had raised the percentage of water-stable aggregates from about 1 to 17%. A year later this had fallen back to 8%; but the loss may be a dilution effect due to inadequate control of the depth of cultivation and is not evidence of decomposition of the conditioner.

Mean values for aggregate analysis on experiment H.9 Block I, which was in the same field as the experiment with the soil conditioner and ploughed out of ley and also sown to winter wheat in the same autumn, are included for comparison.

There was no visible effect of the treatment with Merloam on plant emergence. Nitrochalk equivalent to 6 cwt. per acre was applied in spring. The wheat was healthy, there was no lodging and it was harvested in good condition. The following yields of grain and straw are in grams per plot, expressed on an oven-dry basis:

	No Merloam	Merloam	S.E.
Grain	797	780	±43
Straw	1074	1072	±32

The above data, which show no response by winter wheat to increased water-stable aggregation of the soil, are not unique. This is not to suggest that under certain abnormal conditions—for example the clay sub-soil on which Hayes and Simpson (7) obtained response with radish—factors related to crumb-stability may not be important for certain crops. Pringle and Williamson (13) found that, although in pot experiments the early development of wheat was improved by the incorporation of a soil conditioner, wheat yield in field plots was unaffected.

LEYS AND CROP YIELD: AN AGRICULTURAL PERSPECTIVE

Agriculturalists must be concerned mainly with relatively short-term cropping policies but at the same time must not entirely disregard the influence of systems of husbandry operating over a number of years. Before discussing the implications of this paper in terms of agricultural practice it must therefore be stated that the results given have been obtained on a single soil series, previously under more or less annual tillage, and are for the first cycle only of a rotation of 3 years grass and 3 years arable. Neither the value of the ley in reducing erosion nor its significance in altering the nature of the task and timing of tillage operations can be estimated from the results of these experiments. Only much more extensive and protracted experiment, which has been initiated but is not far advanced, can answer many such questions which agriculturalists should ask.

The influence of leys upon the supply of nutrients to arable crops within a system of alternate husbandry is a subject which has seemed of late to be somewhat overshadowed by the attention given to the influence of grassland on soil structure. It is the main purpose of this paper to redress this balance. It has been suggested that the main effect of leys at Hurley has been to alter the supply of nutrients to a following crop of winter wheat. With the use of moderate inputs of potassium and phosphorus, variation in wheat yield after leys is highly correlated ($r = +0{\cdot}93^{***}$) with variation in the nitrogen status of the soil which results from the manuring, legume content and utilization of the swards (Williams, Clement and Heard (16)). As could be expected, such variation in wheat yield was largely removed by top-dressing with nitrogen fertilizer in spring. With the increasing capital charge on land and the expanding support of the fertilizer section of the agricultural industry, it is perhaps doubtful whether this production of an organic source of nitrogen by the ley represents a significant economy on many arable farms.

Of all the factors in crop production that may be influenced by the ley, the addition of organic matter in sufficient quantity to change appreciably the physical condition of the soil is the most difficult to supplant with economic alternatives. Although it has been shown that changes in organic matter can alter both nutritional and physical attributes of an arable soil under grass, it has not been possible to demonstrate that variation in crumb stability after 3-year leys affected wheat yields.

Better methods for the quantitative assessment of soil structure are certainly required. More information is needed on the physical edaphic requirements of temperate crops. But, nevertheless, there is the implicit suggestion in these results that on many arable soils the importance of leys as a means of increasing crop yields through the physical amelioration of the soil may be over-stressed.

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ADVANCE NOTES ON RESEARCH

THE USE OF A CHANGEOVER DESIGN WITH DAIRY COWS TO DETECT DIFFERENCES IN HERBAGE QUALITY

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Short-period changeover designs in animal feeding experiments offer considerable attractions in trials designed to investigate the effect of quality differences between feeds. They permit economy in animal numbers and feed materials and enable an assessment of major differences in food quality to be made in a comparatively short period of time.

At North Wyke Experimental Station, during 1959 and 1960, changeover designs using a 3×3 balanced Latin square design, with 7-day and with 14-day feeding periods, have been tested to compare winter rations of differing quality fed to dairy cows. In these experiments it has been possible to detect quite small differences in milk yields, even during a 7-day feeding period.

In order to examine the applicability of such short feeding periods to the assessment of herbage-quality differences, comparisons were made during the winter of 1960–1 between samples of S22 ryegrass cut at three different stages of maturity and dried in a Templewood continuous drier. The digestible organic matter in these feeds was determined with wether sheep, using a method based on that of Raymond, Harris and Harker (1). Herbage quality, for milk production, was assessed by Ayrshire cows, using the above design with a 7-day feeding period, all cows being offered 30 lb. dry matter per day. The results obtained are given in Table 1. It was found that the sensitivity of the method was increased when the results of the first two days of each feeding period were discarded, and so all results, except those in column 5, are calculated on a 5-day basis.

The work so far carried out does not differentiate between the effect of lower intake due to low digestibility and the effect of low digestibility in itself. Further work to investigate these factors and the application of the

TABLE 1

	Dry matter intake lb./day*	Digestibility of organic matter %	Digestible organic matter intake lb./day*	Milk yield lb./day*	Milk yield lb./day†
Dried grass, cut 12.5.60 (just prior to heading)	28·1	75·2	21·1	32·1	30·4
Dried grass, cut 2.6.60 (14 days after heading)	26·4	63·4	16·7	26·0	26·3
Dried grass, cut 16.6.60 (28 days after heading)	23·4	55·7	13·0	22·1	23·4
LSD (0·05)	1·1		0·7	1·5	1·7
LSD (0·01)	1·6		1·0	2·1	2·4
CV%	4·9		5·0	6·5	7·4
General mean	26·0		16·9	26·7	26·7

*Using the last 5 days of a 7-day period.
†Using a 7-day period.

*The Grassland Research Section of Levington Research Station.

design to grazing experiments in the field is receiving active consideration. Nevertheless, it can be concluded from the results of this and other feeding experiments, which are yet to be published, that a 7-day feeding period can be of value in demonstrating the effect of feed-quality differences on milk production.

ACKNOWLEDGEMENT

We wish to thank J. C. Dickins, Levington Research Station, for his advice on changeover designs and the statistical treatment of the results.

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A FORAGE WAGON FOR MECHANICAL-GRAZING RESEARCH*

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The design is given of a wagon box that has 2 compartments: one serves as a self-feeding bunk for 8 cows, the other can be emptied into a stationary bunk to feed a like number of cows. Facilities for automatic sampling of forage from 2 fields and procedures for efficient harvesting and weighing are described.

INTRODUCTION

The practice of cutting and feeding green crops as an alternative to field grazing has resulted in the commercial development of self-feeding wagons (1, 2, 3, 4, 6) of fixed design not suited to modification. In the course of planning a series of replicated pasture management experiments with lactating dairy cows (5), involving mechanical grazing, a self-feeder wagon was designed which accommodates, separately, the forage from duplicate fields sufficient for the daily needs of 6 to 8 lactating cows per field. It also provides for representative sampling of the forage from each field.

DESCRIPTION OF THE FORAGE WAGON

Fig. 1 shows the front end perspective and functional components of the wagon box. The box is 14 ft. long, 6 ft. wide and 7½ ft. high, framed with 2×4 in. lumber and enclosed with 1 in. dressed boards; it is mounted on a conventional rubber-tyred farm-wagon chassis.

The self-feeding rack and feed trough (lower left Fig. 1) extend the full length of the wagon. The 4-in. rack slats are spaced 5 in. apart, bevelled to provide 7-in. spaces at the lower 12 in. of the feeder. The lowered suspension of the 15×6 in. trough minimizes spillage of forage. Four 40×40×30 in. canvas sampling bags are hooked in position in separate compartments opposite the feeding rack and removed through openings on the side. The openings are covered by hinged doors when the wagon is in operation. The two pairs of hinged compartment covers (A and B, C and D), each cover half the length of the box and allow forage to be deflected into the respective sampling bags numbered 1, 2, 3, 4, (Fig. 1), into the feeding rack, or into the upper compartment when covers B or D are lowered over the sample containers. The purpose of the hinged divider (E, Figs. 1 and 2) is to keep the bulk of the forage from the second field in the forward end of the raised compartment while loading. Two small hinged doors (each 24×36 in.) are provided at the upper side of the box to facilitate transfer of forage to a stationary bunk.

FIELD OPERATION

A flail-type forage harvester was fitted with an adjustable deflector at the outlet with cord attachment permitting the operator to direct the stream of forage to the front or rear of the wagon.

Fig. 2 shows front-end perspective of the wagon box, illustrating the positions of covers A, B, C and D during each phase of forage collection and sampling from two fields.

Phase 1. During the gathering of forage from the first field (for self-feeding in a dry lot) the compartment covers are as shown in Fig. 2, position 1.

The stream of chopped forage is directed toward the back of the box, gradually filling

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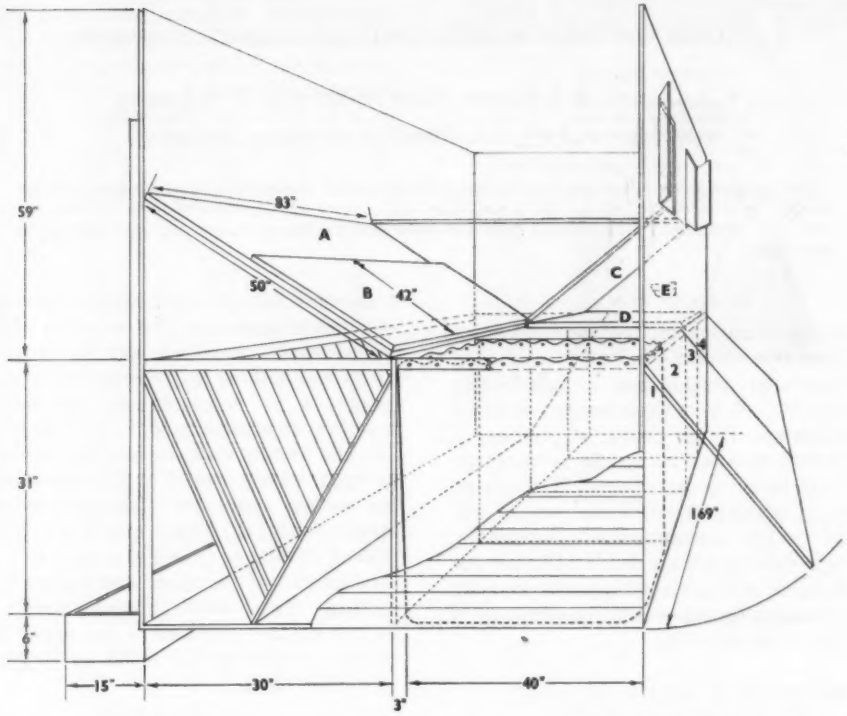

Fig. 1. Front perspective of wagon box, illustrating positions of self-feeding rack, sample containers and hinged deflecting covers.

the rear half of the feed rack. By pulling the deflector cord the tractor operator alternately directs the stream downward into canvas bags 1 and 2, effectively sampling the initial lot of forage as the rack is filled. Each sampling bag holds sufficient green material for chemical analysis and to feed one cow for one day. When sufficient forage is collected from the first field, covers A and B are swung over to the same relative positions as covers C and D (position 1, Fig. 2) to allow the forage to be distributed loosely by fork along the full length of the rack. It is essential to avoid tramping the forage, since compaction causes heating.

Phase 2. Forage can be immediately collected from the second field into the alternate compartments of the box by arranging the covers as shown in position 2, Fig. 2. During this collection the procedure followed is similar to Phase 1, except that sample portions of forage are blown to the rear, falling into bags 3 and 4, and the greater amount is deflected down and contained on covers A and B, bulked forward of the divider E. As the field collection is completed, cover D (position 2) can be closed over sampling bags 3 and 4 and the forage distributed to the rear to avoid spillage while travelling to the dry-lot areas.

WEIGHING PROCEDURE

Before going to the field the wagon is weighed with the four canvas sampling bags in place. At the field, the wagon is linked behind a

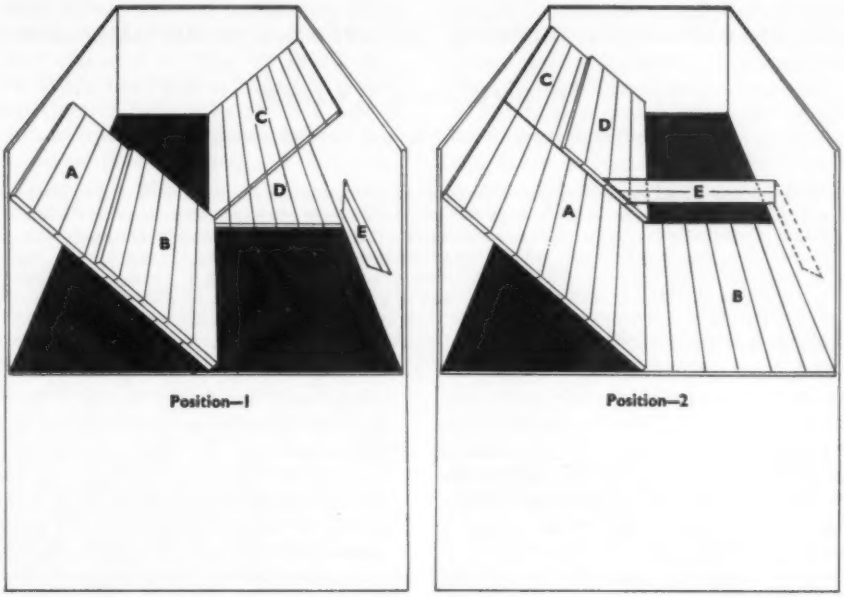

Fig. 2. Front perspective of wagon box, illustrating positions of compartment covers A, B, C and D during two phases of forage collection.

tractor-driven forage harvester and the forage is collected from two successive experimental areas as described above. The loaded wagon is returned to the scale (near the dry lot) and weighed. Sample bags 1 and 2 are removed and individual sample weights are checked against the weight deducted from the load. After transferring the forage portion (from the second field) to the dry-lot stationary bunk, the remainder of the load is weighed and the weights of samples 3 and 4 are determined.

This procedure provides the weights of the respective amounts of green forage from each field and the forage intake of each animal group.

It is suggested that the principles developed in this unit could materially contribute to the efficient conduct of mechanical-grazing experiments. This unit is particularly advantageous in eliminating duplicate hauling and tedious tractor coupling where pastures are remote from the feeding areas.

ACKNOWLEDGEMENTS

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THE ROLE OF GREEN SOILING IN THE ECONOMY OF THE DAIRY FARM

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With modern machinery and modern techniques of grass production, mechanical- or zero-grazing offers a means of utilizing the crop to perfection. Whether this results in enhanced profits depends largely upon the farm and the specific circumstances. It may, it may not. What is evident is that the health of the cows is not affected by an unnatural manner of summer feeding; the sward, *per se*, may be improved by the regular and uniform defoliation; and under conditions of intensive production and the vital need to use profitably every blade of grass, as for instance on small, highly-rented farms, the practice of zero-grazing merits the most careful consideration. It cannot lightly be dismissed as merely a new fad.

The search for greater productivity and more profitable use of the grass crop continues with vigour amongst the enthusiasts in the technical and practical spheres of British agriculture though, alas, much slower progress and a great deal less enthusiasm is observable amongst the majority of farmers in exploiting this superb crop, so ideally suited to the soil and climate of this country. Over the years, the search has been pursued along many avenues and in recent years the path has turned full circle by the resuscitation of the old practice of green soiling, now modernized with a new American name—zero-grazing. Some prefer to call it mechanical grazing. The practice is defined as the process of cutting and carrying to livestock a fresh green crop which otherwise might have been grazed.

Down the years many crops have been treated in this fashion for a variety of reasons and under widely differing circumstances. The practice is widespread in Central Europe and in the tropics. In Europe green soiling has frequently been forced upon producers by the systems of land tenure and inheritance, which have resulted in severely fragmented holdings consisting of widely separated miniature fields completely unsuited to the needs of unattended grazing herds. Under such circumstances to cut and carry the green forage is less time-consuming than herding. Moreover, where land is scarce and more precious than human labour, increased productivity of the land is undoubtedly secured in this way. In Switzerland, for instance, it is as common to see the farmer mowing the grass on a pocket handkerchief of a field and carrying it to his cows, as it is in this country to see large fields being grazed by equally large herds of milch cows controlled by an electric fence. In Switzerland, Germany and Italy, the carting of green forage to the stock is often integrated with organic irrigation, known as Gulle in Switzerland and Germany and as Fertirrigatione in Italy. The impressive results obtained on the Continent indicate fruitful lines of research for workers in this country.

The effect of drought on herbage growth in the tropics, allied to the destructive effect of the trampling by animals, as well as lack of shade, may account for the adoption there of zero-grazing on a large scale. In the United Kingdom the practice, though by no means general, was not uncommon in the 19th century and persisted in many instances until after the first world war. The increasing demand for fresh milk from rapidly growing urban populations and the comparatively poor transport systems then in operation, as well as the perishability of the milk in those days when sterilization of milking utensils, the preparation of cows before milking and the condition of the buildings in which the stock were housed had not attained the high standards of today, dictated that the cows' feed rather than her product should be transported. There

were many instances too where the compulsive force was the need to increase productivity of both land and animals. One of the classical cases was the Soiling Farm at Rawcliffe, Goole, Yorkshire, where the University of Leeds in the 1920's indicated the scope for milk production on arable land by growing a variety of suitable crops for cutting and carting green. The literature on the subject has been very ably summarized by Watson and Runcie (1).

The revival of interest in the practice of soiling has largely come about as a direct result of the remarkable development in machinery in recent years. A wide range of equipment is now available to deal efficiently with the cutting, loading and unloading of a heavy bulk of green stuff, thus overcoming the high labour costs which previously had been its downfall. Moreover, the development of machinery syndicates in many parts of the country makes economically possible the use of expensive machinery on even small farms. Then too, the greater interest in silage-making in the last ten years has resulted in harvesting machinery being purchased for this purpose which can well be used for green soiling as well.

Zero-grazing has the objective of increasing the profitability of livestock production, which it aims to do by increasing output at less than a corresponding increase in costs. Thus there are two parts to the question "does it pay?" which is always posed. Firstly, it must be established whether the productivity of both land and animals is actually increased and secondly, what additional costs are incurred. On the former question the evidence, though not abundant, is more plentiful than on the latter. It is not, however, easy to interpret.

The evidence from commercial farms that have practised zero-grazing in recent years indicates that such factors as the inconvenient layout of fields in relation to the farm buildings as well as poor drainage, which limited the best use of the pastures by grazing, certainly hastened, if it did not necessitate, mechanical harvesting. Clearly in such cases the potential increase in productivity and the additional expenditure which can be justified in efforts to achieve it, is greater than under conditions which are more favourable for normal grazing procedures. In addition on most commercial farms the introduction of zero-grazing has been accompanied by very substantial changes in the management of grass and other forage crops. For example, on one farm it has been associated with the use of the gang mower and the cutting of grass at a very early stage of growth, thus giving the maximum encouragement to the growth of clover. On another farm zero-grazing has been an integral part of the production and utilization of bulky crops of lucerne, maize, kale and irrigated grass. Without zero-grazing it is doubtful if the full potential of these crops would have been achieved and in each case very substantial increases in productivity, as witnessed by heavier stocking rates, have been obtained—presumably resulting in greater profit. On the other hand it is difficult to determine to what extent the increased output is due to higher yields resulting from changes in cultural practices, and to what extent it is due to the elimination of the waste caused by the grazing animal fouling the herbage with dung and urine, trampling much of it under foot and, above all, exercising a measure of selectivity, whereas the impartiality of mechanical grazing ensures complete removal and consumption of the crop. In this connection it is interesting to note how complete is the impartiality of the ingesting animal towards cut forage. Many cases could be quoted where cocksfoot, for instance, rejected by dairy cows offered the varied diet of a Cockle Park mixture in the field, has been eaten with complete indifference, and seemingly relished, when the mixture was cut and carted to them. It may be that to distinguish between increases brought about by improved cultural and husbandry practices, on the one hand, and mechanical cutting and carting on the other, is academic. Perhaps zero-grazing should be understood as a more comprehensive term than the mere cutting and carting to stock of a fresh crop, and that it should be understood as embracing a complete system of intensive production, in which the weight and quality of feed grown would be such that the amount of waste would be intolerably high if the crop were used in the

normal way by the grazing animal. Whereas little is known about levels of waste at different levels of yields of grass and forage crops, it is logical to conclude that the absolute amount of waste would be greater at the higher yields and would justify higher expenditure in order to avoid it. It would, therefore, appear that the chief lesson to be drawn from commercial experience is that substantial increases in the intensity of land use for livestock production can be achieved by intensive grass and forage-crop production, combined with mechanical cutting and carting of the crops to livestock.

There are no data on the costs and profitability of these commercial systems, but increases of cow stocking rates of up to 70% over strip-grazing have been claimed. Increases of this magnitude would clearly be large enough to justify substantial additional expenditure on equipment, fertilizers and so on, and indeed higher costs per cow and per gallon of milk could be accepted and still leave ample margin for higher profits.

Recent experimental results are available from the East of Scotland College of Agriculture, where comparisons between strip- and zero-grazing have been carried out over a number of years (1), and from Seale-Hayne College, where a zero-grazing investigation was begun in 1959 and is still continuing (2). In both investigations the cultural practices applied to the grassland devoted to zero-grazing did not differ appreciably from those applied to the grazing areas. On the other hand, whereas the Edinburgh investigations compared in detail strip- and zero-grazing, at Seale-Hayne the work has primarily been concerned with examining the problems involved in zero-grazing *per se* and less emphasis has been placed on precise observation of the grazing herd. To the extent that the experiments ran in parallel the results show considerable similarity.

The investigations at both centres show that cows react well to continuous housing and hand-feeding of grass. Health and bodily condition remained good and conception rates were maintained at the level of the grazed cows.

As far as the productivity of the system is concerned, only the Edinburgh investigation was concerned with a direct comparison of grazed and zero-grazed herds. Even so, the most direct measure of relative productivity—gallons of milk produced per acre under different systems—cannot be obtained because of the difficulty of matching two herds of equal potential milk-producing capacity. Indeed, at Edinburgh the strip-grazed herd produced the greater amount of milk per cow and per acre, but the yields of the strip-grazed cows at the beginning of their lactations were higher, suggesting that they were generally cows of higher potential capacity than the cows in the zero-grazed herd. On the other hand the persistency of milk production during a lactation was the same for both zero-grazed and strip-grazed cows and there is nothing in the evidence to suggest that a cow of given capacity will not perform as well under zero-grazing conditions as under normal conditions. There is, therefore, no reason why indirect measures such as the stocking rate and the grazing days per acre should not provide valid bases for conclusions. In the Edinburgh investigation zero-grazing required 0·7 acres per cow over two summer-grazing periods, compared with 0·77 acres per cow for strip-grazing. At Seale-Hayne the zero-grazed cows were kept during the grazing season on the produce of 0·8 and 0·7 acres of grassland in 1959 and 1960, respectively. In the Edinburgh investigation an increase of about 10% in stocking rate was achieved by zero-grazing and at Seale-Hayne the increase was estimated to be in excess of this. At Seale-Hayne these increases in productivity of grass by zero-grazing were achieved at moderate levels of grassland management represented by a yield of dry matter of between 45 and 46 cwt. per acre.

One may conclude, therefore, that zero-grazing increases the productivity of grassland, although the increase may be moderate at moderately intensive levels of grass production. Possibly very substantial increases in productivity can be secured at the most intensive levels of grass and forage crop production, and this aspect of the problem will be investigated in future years at Seale-Hayne.

Unfortunately, one cannot say unequivocally whether, in addition to increasing productivity, zero-grazing also, in all circumstances, leads to higher profits. Certainly the cash value of the additional output can be calculated. If one takes the results of the experimental data as indicating the modest increase of 10 per cent in the productivity of summer grazing, it would be realistic to assume that part of the gain would be taken in the form of an increase in the amount of grass conserved for winter use, so enabling additional cattle to be kept the year round. This is more prudent than to consider the production of additional summer milk only. Thus with a herd of 50 cows an increase in the effective use of grass which enabled 5 additional cows to be maintained during summer should, if part of the increase were conserved, alternatively enable at least 2 additional cows to be kept the year round. At present prices the value of the output of the two additional cows might commonly be of the order of £250 to £300. Of this additional revenue, increased costs would absorb some proportion, but the proportion would vary greatly according to the existing circumstances on the farm—the important circumstances being the nature of the buildings for housing stock, the kind of machinery already available, the existing pressure of work on the labour force and the availability of straw for bedding. Where efficient facilities are available for the feeding of bulky foods to stock (as they frequently are in systems of loose housing) and where silage is made by forage harvester and moving-floor trailers, additional capital costs might be negligible. General experience is that the zero-grazing routine fits in well with silage-making operations, and, except where labour is unduly hard-pressed, it may well be possible to fit it in by closer attention to work organization without incurring any additional expenditure on labour. On farms practising mixed husbandry, straw might be abundant. In such exceptionally favourable circumstances the additional cash cost would amount only to those now fashionably described as variable costs and would consist of tractor fuel, concentrates, veterinary bills and medicines and minor miscellaneous expenditure for the additional cows. In total, these would not be likely to exceed about £75, leaving a net addition to profit of £175 to £225 per annum.

In less favourable circumstances where additional expenditure would need to be incurred for say labour, straw, and some capital expenses, one would need to determine in the light of this estimate of the excess over variable costs what level of expenditure one could afford. If, for example, the labour position on the farm was such that additional labour, possibly in the form of overtime, would be needed, experience at Seale-Hayne is of some help. Here with a zero-grazing herd of 24 cows there was a net extra labour requirement of 90 minutes a day. If due allowance is made for some inefficiency caused by the exigencies of experimental work but also for some economies of scale, the net extra requirement of, say, a 50-cow zero-grazed herd as compared with a strip-grazed herd would not be less than 2½ hours a day during the grazing season of about 180 days—a total of 450 man hours. At overtime rates this would amount to an expenditure, in round figures, of £125. Deducting this sum from the contribution to profits previously arrived at of £175 to £225, a sum of only £50 to £100 would be left available, and if straw had to be bought, or indeed if there were a good market for the straw, then litter would more than absorb this surplus, leaving nothing for the support of any capital expenditure required and as recompense to the producer. In larger herds the gain would be greater and in smaller herds smaller, but in general one is forced to the conclusion that, at moderate levels of intensity of grassland management, zero-grazing is only likely to increase profits where facilities to carry it out already exist and where few additional costs will be incurred.

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COMPARISONS OF GRASS VARIETIES FOR SURFACE SEEDING UPLAND PASTURE TYPES

I. *Molinia* AND *Nardus* PASTURES

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A series of experiments was laid down in 1957 on different upland vegetation types in Scotland to provide a basis of critical information on the performance of 18 herbage varieties. The present paper deals with results on areas dominated originally by *Molinia* and *Nardus* at Sourhope farm, Roxburghshire. Data obtained between 1957 and 1959 are discussed in relation to sward development, competition with remnants of native herbage and seasonal productivity.

INTRODUCTION

The basic techniques of renovating pasture by surface treatment were worked out 30–40 years ago by investigators in Scotland and Wales. Today the potential of surface seeding is more widely appreciated and recent progress on a considerable scale in the north and west of Scotland has demonstrated its value and its application to extensive forms of pasture management.

Norman and Green (6, 7) refer widely to various aspects of surface treatment, while Grant (3) has described surface seeding in Scotland. A survey in the north of Scotland (4) emphasized the importance of extensive exposure of the soil surface and an abundance of surface moisture, even saturation, for successful early establishment.

Although numerous observation trials were laid down in Wales and Scotland before the war (1, 9) no data on the agronomic characteristics of present-day varieties for surface seeding appear in the literature.

EXPERIMENTAL

Layout and methods

Twenty treatments, common to all sites, were laid out as randomized blocks with four replicates. The plots measured 15 × 9 ft. and the experiment covered ¼ acre. Eighteen of the treatments were single grass varieties, each sown with S184 white clover at 2 lb./acre. The remaining treatments consisted of S184 sown alone at 6 lb./acre and "unsown" which received only the standard manurial application. Seed rates of the grass varieties are shown below:

	lb./acre
Perennial ryegrass S24	30
,, ,, S23	30
Meadow fescue, Danish Trifolium	35
,, ,, S53	35
Cocksfoot, Danish Trifolium	20
,, S143	20
Timothy, Scots	16
,, S48	16
,, S50	16
Tall fescue S170	35
Yorkshire fog	25
Red fescue Danish	12
,, ,, S59	12
Rough-stalked meadow grass, Danish Trifolium	8
Smooth-stalked meadow grass, Danish	8
Crested dogstail, N.Z.	16
Bent, N.Z. Browntop	8
Meadow foxtail, Finnish	30

The Yorkshire fog sample consisted of ryegrass cleanings containing 60% fog and 25% ryegrass; the latter had a germination of only 35%. Germination figures for all varieties were satisfactory except in the case of meadow foxtail which was only 34%.

In experiments of this kind, mainly in rather

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inaccessible areas, it is impracticable to use conventional techniques of assessment, and most of the data are qualitative, based on visual estimates supported by monthly notes throughout the year. For the analysis of variance, the score data were transformed to degrees, ($y = \text{arc sin } \sqrt{P\%}$). Least significant differences (LSD) are given for $P < 0{\cdot}05$.

A minimum of the available data is presented to enable the salient agronomic features to be described, but the complete data have been lodged for reference in the library of the Hill Farming Research Organization.

Soils and vegetation

The *Molinia*-dominant site lies at 1000 ft. on a peaty gley overlying drift derived from Andesitic lavas. The upper horizon of peat is 8–10 in. deep with a pH of 4·4. For agricultural purposes, the lime requirement was originally high and available phosphorus very low, though potash was only moderately deficient. A species list of the original vegetation, with subjective frequency estimates is: *Molinia caerulea*—dominant (about 70% ground cover), *Nardus stricta*—very abundant to co-dominant, *Festuca ovina*—abundant, *Agrostis canina*—rare, *Deschampsia flexuosa*—occasional to frequent, *Vaccinium myrtillus*—frequent, *Potentilla erecta*—occasional, *Trichophorum caespitosum*—rare.

The principal bryophytes were *Pleurozium schreberi* and *Hypnum cupressiforme*.

The *Nardus* site was situated on a moderate slope at about 1300 ft. overlying a freely drained peat podsol with discontinuous iron pan (5). The surface peat, about 4 in. in depth, was more fibrous than at the *Molinia* site, with a pH of 4·0. The original vegetation showed the following floristic composition: *Nardus stricta*—dominant, *Festuca ovina*—abundant, *Deschampsia flexuosa*—abundant; these three species contributed about 90% of the ground cover; *Anthoxanthum odoratum*—abundant, *Agrostis canina*—frequent, *A. tenuis*—rare, *Galium hercynicum*—abundant, *Luzula multiflora*—frequent, *Carex binervis*—frequent, *C. panicea*—frequent, *Potentilla erecta*—frequent, *Juncus squarrosus*—frequent, *Trichophorum caespitosum*—rare, *Vaccinium myrtillus*—locally frequent.

The bryophytes included *Hypnum cupressiforme*, *Rhytidiadelphus squarrosus*, *Pleurozuim schreberi* and *Plagiothecium undulatum*.

Pre-treatment

Before treatment, both experimental areas were markedly under-grazed and the sward at the *Nardus* site was particularly dense. The *Molinia* site showed the typical hummock formation common in Molinietum but, as the hummocks were only moderately developed, some bare ground was present between them. Although a satisfactory burn was obtained on the latter area, the herbage did not dry out sufficiently at the *Nardus* site to enable an effective burn to be made. Pre-treatment and early management details at both sites are shown below:

1957 *Molinia* site

7 April—Burnt.
2 May—Harrowed 6 times with a weighted grass harrow. Numerous clods and tussocks combed out and cleared.
8 May—Ground limestone at 3 tons/acre.
28 June—Harrowed twice with a heavy ripper. Very good sowing surface produced but "hummocky".
17, 18 July—Superphosphate at 6 cwt./acre. Nitro-chalk at 1 cwt./acre. Sown—conditions wet.
9 August—Grazed, 30 hoggs for 2 days to consolidate surface. Plenty of keep from regenerating *Molinia*.
4 November—Grazed, 50 ewes for 3 days.

Nardus site

7 May—Harrowed 4 times with a weighted grass harrow—little effect on the turf.
7 May—Ground limestone at 3 tons/acre.
28 June—Harrowed 5 times with a heavy ripper. Owing to toughness of herbage, result poor.
15 July—Harrowed twice with a heavy ripper. Denser clumps of *Nardus* persisted.
16, 17 July—Superphosphate at 6 cwt./acre. Nitro-chalk at 1 cwt./acre. Sown. Conditions damp.
4 November—Grazed, 50 ewes for 3 days.

The seed bed at the *Nardus* site could not be considered satisfactory, but in the absence of burning or heavy preliminary grazing, which was impracticable in this case, penetration of the tines was poor.

Management

The only manurial application after sowing was a top dressing in April 1958 of 4½ cwt./acre of CCF (5:12½:12½). In order to ensure the opportunity for regular and systematic observation, a controlled management was adopted whereby both sites were enclosed and grazed 4 times by sheep in each year. Growth, however, was allowed to accumulate in July and, since cattle grazing was not possible, this was mown and either raked or grazed off.

WEATHER

The two years 1958 and 1959 provided a great contrast in weather—the latter was exceptionally dry and sunny (9·6 in. rainfall and 1059 hr. sunshine between April and September).

RESULTS

A. *Molinia*-dominant site

Early establishment

Two months after sowing, it was disappointing to note that only a few plants of white clover, in small damp pockets, had established. Despite the severe harrowing, *Molinia* and associated grass species were growing strongly. Towards the end of October 1957, the ryegrasses and Scots timothy were outstanding. The position of all varieties at this time is summarized below by mean scores for development and vigour, (0–5):

4·0—S23.
3·4—S24; Scots timothy.
3·1–2·9—S170; fog; RSMG; Trifolium cocksfoot; S48.
2·3–2·0—S143; dogstail; S50; S53; S59; Trifolium meadow fescue; bent.
1·8–1·6—SSMG; Danish red fescue, meadow foxtail.

LSD=0·6

Sward development

By mid-May 1958, the *Molinia* was reduced to a few shoots at the tussock bottoms and the regenerating natural vegetation was formed principally of *Nardus*, *F. ovina*, *D. flexuosa* and *Agrostis* spp. These species formed 50% of the cover on "unsown" and the clover treatments, the remainder was bare ground. The failure of clover was a prominent feature of the trial at this centre.

The three timothy varieties and RSMG showed the most dense swards with ground covers of 41–46% compared with the ryegrasses and dogstail at 35%. The cover of the remaining varieties ranged between 20 and 30%, except for Danish red fescue which was barely 15%. In the spring of 1958, therefore, bare ground varied on all plots between 15 and 45%, but by the following October it was reduced to less than 10% practically overall. The replacement of bare ground with regenerating natural vegetation during this period, spring–autumn 1958, continued on the "unsown" and clover plots until it contributed nearly 90% of the ground cover. On the grass plots, however, the relative contribution of sown grass, bare ground and regenerating herbage varied considerably between varieties and provided a clear indication of their relative aggressiveness and "early-sward-forming" abilities.

Taking sward-forming ability as a criterion, the varieties at this site fall into four more or less distinct categories:

1. Varieties showing variable densities initially, which not only filled in the bare ground, but competed aggressively with and reduced the natural vegetation, e.g. RSMG, Yorkshire fog, S59, Danish red fescue, S50, S23, SSMG.

2. Varieties which increased in ground cover but which allowed at least some increase in cover of the natural herbage, e.g. Danish meadow fescue, S53, crested dogstail, S48, S170 and Scotch timothy.

3. Varieties which maintained their initial status but which did not prevent replacement of bare ground by other vegetation, e.g. S24, S143 and bent.

4. Varieties which failed to maintain their initial status and were replaced to some extent by other vegetation, e.g. Trifolium cocksfoot and meadow foxtail.

The progression of ground cover values in 1958 and 1959 is illustrated in Fig. 1. The histograms indicate that by the end of the second year no variety showed a deterioration

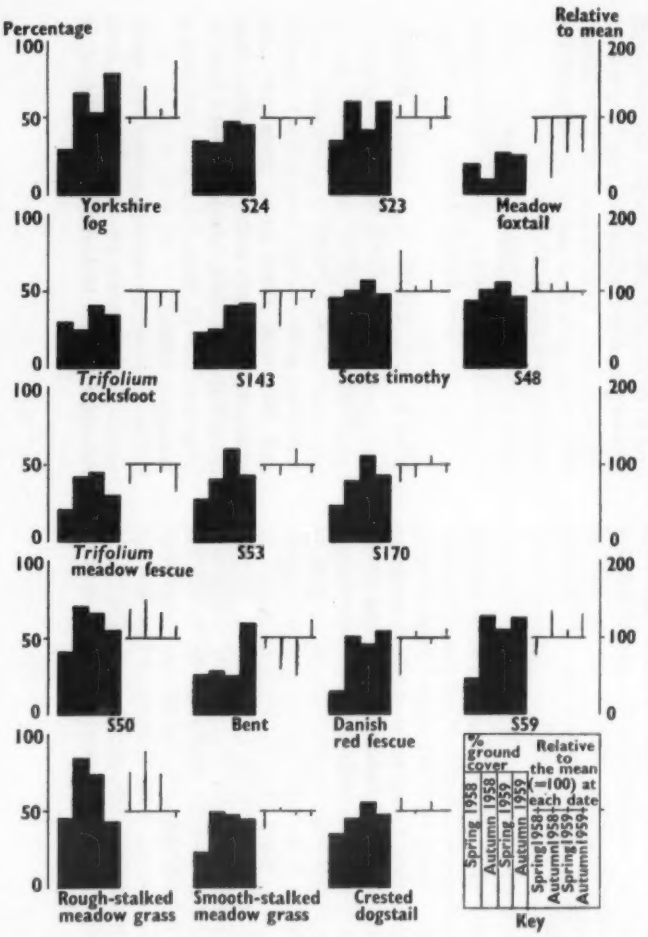

Fig. 1. *Molinia*-dominant site. Sward development—the contribution of sown grass to the ground cover 1958–59.

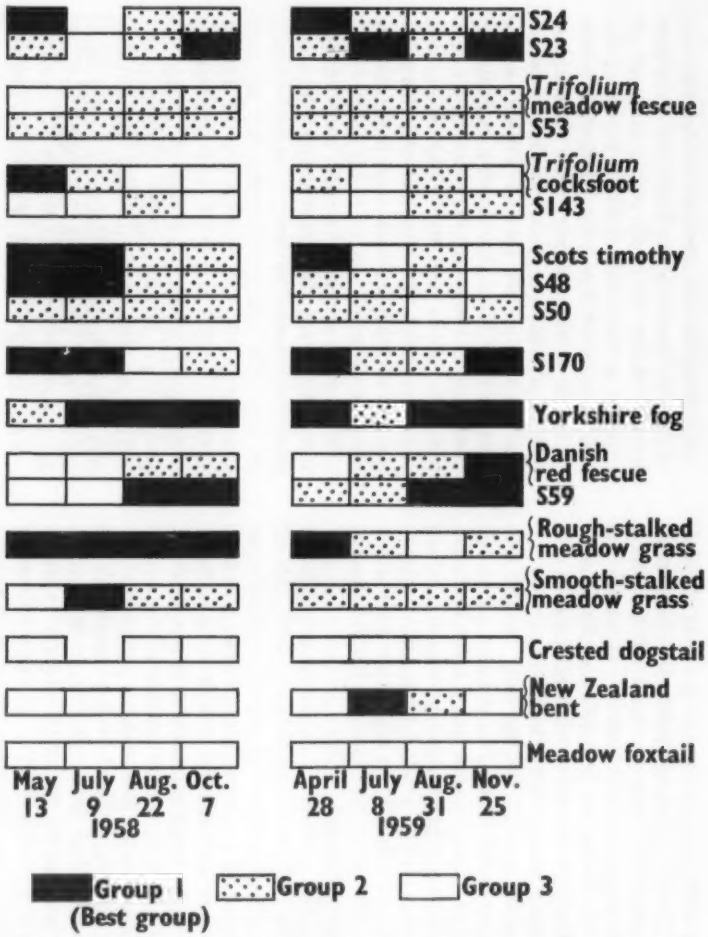

Fig. 2. *Molinia*-dominant site. Relative productivity—three classes based on each date. (Full explanation in the text).

in ground cover below the spring 1958 value. The line diagram alongside the histograms expresses the data in terms of the mean performance of all varieties at each date (=100). Thus, the best and poorest varieties are readily observed, and relative differences in rate of development more easily seen.

The outstanding change early in 1959 was the improvement of S170, meadow fescue and dogstail. Later in the year, only Yorkshire fog increased aggressively, forming an excellent sward of >80% ground cover. Bent, having developed very slowly, also showed a marked increase, while S23 and both red fescues maintained swards >50%.

The dry summer of 1959 adversely affected all the timothies, particularly S50, though they still maintained a ground cover in the region of 50%. The meadow fescues and S170 were similarly affected, but RSMG suffered most of all and a big decrease in ground cover in this species was accompanied by a proportionate increase in natural vegetation.

By autumn 1959, all the bare ground in the "unsown" and clover plots had been completely colonized by natural vegetation; most plots contained 45–55% of this component. Yorkshire fog, however, contained only 17%, whereas in Trifolium cocksfoot, meadow fescue and foxtail plots native species formed 60–70% of the sward. White clover was nowhere more than a trace.

Productivity

The importance of growth habit in relation to aggressiveness and sward-forming characteristics needs no emphasis. Within wide environmental limits, habit is a fairly constant specific and varietal characteristic, and as the habit of varieties studied in these experiments is well known, no detailed discussion is necessary. It is important to recognize, however, that where productivity is estimated, as in this case, the values are arrived at by consideration of the two components, height and density of herbage. For example, S170, S24 and RSMG might be given the same productivity score, S170 because of superior leaf length, RSMG for density and S24 for a combination of moderate length and density.

Productivity estimates for four dates in each of the two harvest years have been calculated in relation to the mean performance of all varieties at each date (=100). In Fig. 2 the varieties at each observational date have been placed in three categories. The data seldom fall into well-marked groups and the categories are based on an average or mid-group whose range is the LSD and with the mean value as mid-point of the group. The other two categories lie above and below this group respectively. (The LSD serves as a valuable guide but is not rigidly adhered to if more realistic groups emerge).

The main seasonal trends and varietal comparisons are clearly evident in Fig. 2 and are not elaborated in the text.

1958

Observations for 1958 are presented for 13 May, 9 July, 22 August, and 7 October, reference in the text to these dates being respectively spring productivity, early mid-season, late mid-season and autumn productivity.

Early spring growth is of particular interest, and S170 showed active growth several weeks before any other species, though the sward was very open. Some indication of the condition of the herbage is shown by estimates for height (in.) made on 13 May:

6·0–5·7—S170; Trifolium cocksfoot.
5·2–4·7—Scots timothy; S24; S53; Trifolium meadow fescue; Danish red fescue; S48.
4·0–3·5—S59; SSMG; fog; foxtail; RSMG; S23; S50; S143; bent.
2·0—Crested dogstail.
LSD=0·7

Among group 1 (best group) Scots timothy and S48 were particularly prominent and superior to the very early growing Trifolium cocksfoot and S170 by virtue of sward density. In group 3, S143, bent and foxtail had only a negligible value.

Observations in early mid-season were made very difficult by the accumulation of tall rank natural herbage and no realistic figure is

available for the ryegrasses and dogstail. After mowing, 95% of the material was consumed by sheep and the late mid-season figures represent growth from a uniform stubble. Many of the varieties in early mid-season had an impaired value, due to their tendency to form a profusion of heads, e.g. RSMG, SSMG, bent and S50. The outstanding herbage was produced by S48 and although RSMG had a high figure it was very stemmy and had been undergrazed in spring.

In late mid-season, varietal differences were not of a large order, particularly within group 2, but notes taken at the time indicate that S50, S23 and S59 were most useful, whereas the cocksfoot looked nitrogen-deficient. A notable feature at this time was the improvement in red fescue, especially S59, and by autumn the performance of this variety was approaching that of fog and S23.

In early October, regenerating *Agrostis* was very vigorous. Most varieties were green, showing only minor tip burn, but cocksfoots, Scots and S48 timothy were more severely burnt. The degree of autumn growth since the previous grazing in late August is shown below by height (in.) measurements:

8·4—S170.
7·1–5·9—RSMG; S53; S24; Trifolium meadow fescue.
5·6–4·5—S59; Trifolium cocksfoot; fog; S143; SSMG; Scots timothy; S48; S23.
3·3–2·6—Danish red fescue; foxtail; S50; bent; dogstail.

LSD=1·4

1959

During the late winter, S50, both red fescues, fog, RSMG and dogstail were easily discernible owing to their superior colour and density. There was no growth of any account by mid-March, though S170, S143, S48, S24 and meadow fescues were readily picked out. RSMG formed a close dense carpet of good colour, but bent was uniformly brown.

By the end of April, S170 had a ground cover of >50% and was nearly twice as tall as most other varieties, which were 3½–4½ in. high. It was significantly more productive than all others in the best group. The plots were grazed at the beginning of May and again at the end of the month, since, aggravated by dry conditions, many varieties were running rapidly to head, e.g. red fescue, S24, dogstail, SSMG and foxtail. The herbage was very dry, S23 and RSMG suffering most in this respect, whereas S53 did not have the same desiccated appearance. These factors together with a 6 in. growth of regenerating herbage made accurate scoring for productivity impossible, but it was evident nevertheless that S170, the timothies and S53 formed a superior group.

In early mid-season, the natural vegetation was rank and stemmy and, in addition, RSMG, SSMG and fog bore a profusion of stems which reduced their value. Experimental errors are, therefore, high for the productivity observations, but the increased value of S23 and bent, which is shown in Fig. 2 had a very real value when seen in the field.

After cutting, the area was allowed to freshen for a few weeks and then grazed hard at the end of July, following which the area was not only very uniform, but greener than for some time. The late mid-season figures represent growth during the very dry month of August; though short (the best=5 in.) it was surprisingly green. Only fog and S59 were satisfactory at this date, the remainder showing little advantage over the plots where no seed was sown. S50 and RSMG were badly dried up (the latter never recovered from the May drought in the same way as S23) and, with dogstail and foxtail, were of practically no grazing value at this time.

The advantage held by fog and S59 was carried on through an eleven-week period of very slow growth to the end of November. Height at this date ranged from 6 in. for fog to 3 in. for cocksfoot and 1½ in. for bent. Colour differences were very marked, due mainly to previous drought effects, and the following estimates on a scale 0–5 (5=completely green), summarize the position:

4·5–3·9—Yorkshire fog; S59; S24; S23; S50; Danish red fescue; dogstail.

3·5–3·0—Trifolium meadow fescue; RSMG; S143; S53; SSMG; Trifolium cocksfoot; S48.
2·5—Scots timothy; S170.
<0·5—Meadow foxtail; bent.
LSD=0·9

Bent, having improved greatly in 1959, was dense and produced as much leafage as fog, but unfortunately became rapidly discoloured, reducing the value of this grass to a negligible position.

The overall performance in 1959 was much affected by the dry summer and RSMG and timothy varieties were particularly influenced. Even so, they were never surpassed by cocksfoot until the autumn, when S143 became superior.

Discussion

Despite the satisfactory nature of the pre-treatment at the *Molinia* centre, regeneration of the remnants was vigorous and had a pronounced effect on the results. The reaction of the varieties to this competition has been indicated in the section on sward development. In general, the pattern of sward development followed a sequence to be expected from available knowledge of varietal characteristics.

The pattern of productivity during the first year bore a close relationship to known characteristics of seasonality and, in general, Yorkshire fog, S59 and the meadow grasses showed to relative advantage under the conditions of low fertility and the absence of applied nitrogen after April 1958. The high-fertility-demanding species, the cocksfoots and S24 in particular, showed signs of inadequate nitrogen supply, while S170 gave an unexpectedly satisfactory performance. Meadow fescues showed to advantage, not so much in their capacity for high productivity as in their ability to produce consistently satisfactory growth, a feature which continued throughout the second year.

Rough-stalked meadow grass was consistently good, except under drought conditions, but was not very palatable to sheep, tending to be undergrazed in spring and producing a profusion of stems in early summer. New Zealand bent was poor throughout, owing partly to its slow development and a tendency to die back from early autumn to early summer. Dogstail proved very palatable to sheep, but its value was reduced by the numerous stems produced in summer, and over the winter it was inferior to S50, S23 and red fescue.

1959 was complicated by drought conditions and the tendency of some varieties to run to stem was aggravated. S143 and S53 improved during the second year and, at times, the latter was as good as or even better than S23. The superiority of fog and S59 in the autumn was maintained over the winter 1959–60, and was still manifest in spring 1960.

White clover was consistently very poor. The initial establishment was sparse and there was no indication of progressive development over the two years; the plants that did establish showed little tendency to spread.

To place varieties into classes of agronomic value is unwise in a pilot study of this kind. In the final discussion, however, some attempt is made to place the varieties in an order of usefulness for various conditions of surface seeding, using the experimental data together with observational material from a variety of conditions in practice.

B. *Nardus*-dominant site

Early establishment

Seven weeks after sowing the initial take was good, and particularly favourable on the bare patches. Although the general position was satisfactory, *Nardus* persisted in quantity after the pre-treatment, and its distribution was not uniform. Since the presence of *Nardus* could be expected to have an adverse effect on establishment, ground cover of this species was assessed on each plot. The majority lay within the range 30–40% persistent *Nardus* cover.

In contrast to the previous site, white clover initially grew well and N.Z. bent was more advanced than is usual so soon after sowing.

A rapid establishment of ryegrass, cocksfoot and timothy was noted.

By 21 October, three months after sowing, it was apparent that subsequent growth had not been so satisfactory, more than half the varieties having a height of less than 3½ in. while dogstail was barely 1½ in. Yorkshire fog, Scots timothy and Trifolium cocksfoot were 5–6 in. high. The latter was badly burnt. The outstanding varieties in the first autumn were Yorkshire fog and S23, while those at the other extreme were S170, meadow fescue, foxtail, SSMG, dogstail and red fescue; bent, though not in the best group, showed exceptional growth for this species. When grazed in early November, only the cocksfoot varieties were not fully utilized.

Sward development

One characteristic of this site, compared with the *Molinia* area, is the longer period before a pattern of sward development emerges. This is mainly due to the limited amount of bare ground present after pre-treatment, which, by spring 1958, had been completely colonized by the sown grass and/or the regenerating remnants of the original vegetation. Apart from *Nardus*, this was composed of "other" species, mainly *F. ovina*, *Anthoxanthum* and *Agrostis tenuis* which itself responded well to the manurial treatment. Two groups, namely *Nardus* and "other" grasses, were present in roughly equal proportions, and this position was more or less maintained throughout 1958, giving rise to severe competition.

Fig. 3 shows that in the spring of 1958, the ground cover of the eighteen sown varieties varied from 10–50% and in about half of them this changed very little during the year. Nine of the varieties show an increase in cover, which was substantial in the case of S23, and well marked for S53, S143 and for both the red fescues, though their early cover was much lower than the ryegrass. The pattern of development is complex, because of differential rates of establishment and different degrees of further development or deterioration. While this is interesting, for the sake of brevity it is not intended to discuss it fully, and a simple analysis is given below:

(a) From Fig. 3 it is obvious that dogstail, foxtail and S170 were poor throughout.

(b) Eight varieties, though they varied among themselves in initial development, produced satisfactory swards by the spring of 1959, with cover densities of 40–50%. The degree of subsequent deterioration during the dry summer is seen in the following figures representing mean ground cover percentages in November 1959:

	Sown	*Nardus*	Unsown
S59 and bent	31%	35%	34%
Danish red and meadow fescues, SSMG and Trifolium cocksfoot	24%	42%	34%
Scots and S48 timothy	11%	55%	34%

S143 is not included above because of indifferent early behaviour; by the autumn, however, it was superior to the Trifolium variety.

(c) Six varieties, with more rapid early development, formed, by May 1959, excellent swards of 60–75% cover. Subsequent behaviour is seen from the autumn 1959 figures.

	Sown	*Nardus*	Unsown
Yorkshire fog; S23; S50	40–49%	24%	30%
S24; RSMG; S53	33%	37%	30%

A pronounced peak in sward cover in spring 1959 is shown by most varieties, giving at the time a definite improvement over the regenerating vegetation. The latter, owing to the response of *Agrostis* to the pre-treatment, was of useful grazing value, though most plots also contained a *Nardus* cover of 30%.

The importance of rapid initial establishment and development is demonstrated by the performance of the varieties where this occurred. Undoubtedly, the dry season of 1959 had a profound influence on varietal performance and in a less extreme season it is likely that S24, RSMG, Scots and S48 timothy would have given better results. It is of great interest, however, that in view of the rigorous conditions, the so-called "slow starters" progressed as well as they did.

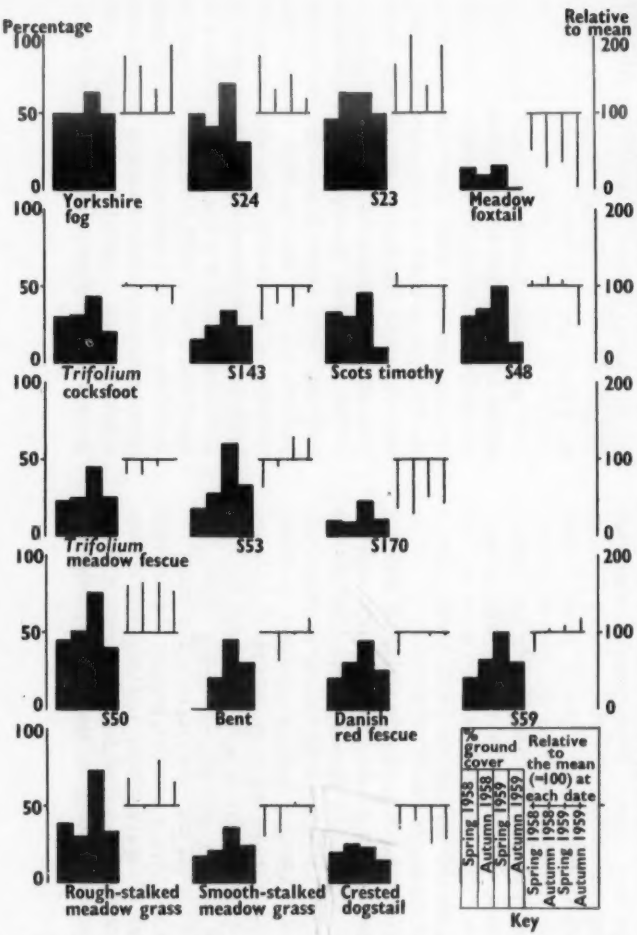

Fig. 3. *Nardus*-dominant site. Sward development—the contribution of sown grass to the ground cover 1958–59.

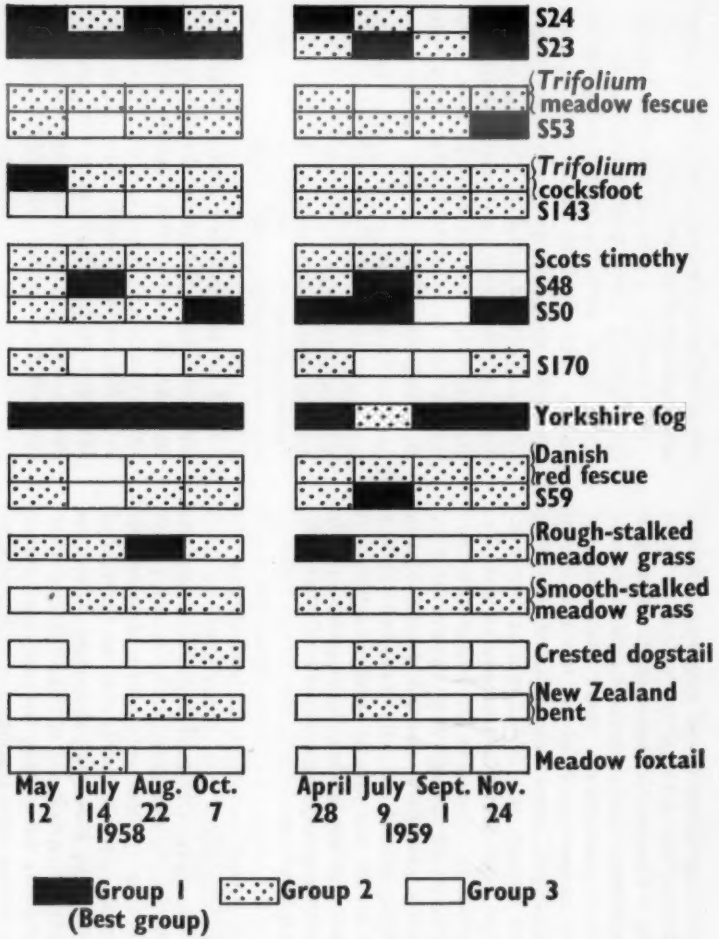

Fig. 4. *Nardus*-dominant site. Relative productivity—three classes based on the mean at each date. (Full explanation in the text).

Although white clover made a promising beginning, it did not maintain its early vigour. Throughout the period considered it made little or no impact on the sward, though by the end of 1959 there was some evidence of improvement.

Nardus showed a striking reduction only in the S50 plots, where it declined from 30–20% between spring 1958 and autumn 1959. This is an interesting feature, since, where the ground cover of other varieties increased, it was at the expense of the "other" grass species. The persistence of *Nardus* emphasizes the importance of thorough initial destruction by cultural or other treatment, especially where grazing is by sheep alone.

Productivity

The main comparisons and seasonal trends are seen in the group presentation in Fig. 4.

1958

The first observations were made on 12 May and an impression of the growth and appearance of the varieties at this time is gained from the height (in.) classes below:

5·1–4·8—Trifolium cocksfoot; Scots timothy.
4·5–4·3—S24; fog; S170; Trifolium meadow fescue; S48.
3·7–3·0—S143; Danish red fescue; SSMG; S59; S23; S53.
2·9–2·0—Crested dogstail; RSMG; bent; S50; foxtail.

LSD=0·9

At this date, the "other" grass species were green and vigorous and compared well in appearance with the majority of the sown varieties. Yorkshire fog was in fact the only variety giving a definite overall superiority over the "unsown", though the ryegrasses, Trifolium cocksfoot and the timothies, particularly S50, were also of grazing value.

When grazed on 19 May, the *Nardus* was mainly untouched, but all the sown varieties (including RSMG—unpalatable at the *Molinia* site) and the "other" grass species were closely grazed.

Subsequent growth was rapid, with cocksfoot and timothy outstanding, but by mid-July the rank and stemmy regenerating vegetation was very prominent. This, together with the profusion of stems on the dogstail plots, made scoring very difficult; in addition, sown bent could not be separated readily from unsown and both these species are omitted from the data for 14 July. The ryegrasses were also heading but bore plenty of leaf at the base. Cuts taken with the Tarpen trimmer show that only the fog, S23, S48, S24 and Scots timothy plots were an improvement over the regenerating vegetation alone. As far as the sown grass itself is concerned, only the first three were outstanding, especially Yorkshire fog.

In the absence of cattle, the plots were mown and then grazed with sheep, raked and trimmed to a uniform height. By the end of August, the ryegrass rapidly attained a prominent position, due to outstanding growth, S23 being the most impressive.

Further observations were taken on 7 October, six weeks after the August grazing. All varieties grew well during the autumn as the following height (in.) figures indicate:

9·4–7·9—Trifolium cocksfoot; Scots timothy; Trifolium meadow fescue; S170; S48; S53.
7·1—Yorkshire fog; S143.
6·4–5·8—S50; foxtail; S24; S23; S59.
5·5–4·5—SSMG; Danish red fescue; RSMG; bent.
3·1—Crested dogstail.

LSD=1·6

This growth, while green and vigorous, should be considered in relation to the ground cover estimates shown in Fig. 3. It becomes clear that only fog, S23, and S50 produced relatively dense swards with a useful amount of growth at this period. Colour was generally satisfactory, except for bent which was estimated as 50% discoloured; Scots and S48 timothy were about 30% discoloured. Over the year, apart from ryegrass and fog, only occasionally was some benefit derived from a sown grass over regenerating herbage. S143 was particularly disappointing and Trifolium

Fig. 3. *Nardus*-dominant site. Sward development ... sown grass to the ground cover 1958–59. ... the mean at each date. (Full explanation in the text.)

cocksfoot did not improve after good early growth. In fact, the timothies were much more impressive.

1959

During late winter (mid-February) the experimental area was very brown in appearance, due partly to the persistent *Nardus*, and among the varieties only S50 was outstandingly green. In early April the colour improved, and it was noteworthy that no plot was superior to indigenous *Anthoxanthum* in this respect. S170 produced the earliest growth but was very thin.

Detailed observations at the end of April revealed, as described, a marked increase in the cover-density of nearly all varieties. In addition, the clover, hitherto very low in cover, was spreading and looked vigorous. There were marked differences between the varieties, and S170, though thin, had produced a quantity of herbage 7½ in. high. (Most other varieties were 4–5½ in.) Its value in Fig. 4 is for this reason undoubtedly overestimated, but has a high potential at this time of year. The cocksfoots were still showing a lot of burn and S143 was very poor in this respect, not having produced as many green shoots as the Trifolium variety. Since S24 had spread markedly, its earlier growth gave it a marked superiority over S23, and together with fog and S50 it formed an outstanding group. Despite the dry conditions in May, re-growth was rapid after the spring grazing. Most varieties were leafy, but the ryegrass, especially S23, was showing the adverse effects of drought; by comparison S53, though not productive, looked leafy and vigorous.

By 28 May, many of the sown varieties were running to stem and sheep were put to graze the area again. They utilized about two-thirds of the sown grass but little of the *Nardus* and "other" grasses, which stood out in head 8–10 in. above the well-grazed sown species.

Growth was allowed to accumulate for six weeks, when most plots were dominated by the dense, fibrous, natural vegetation. S23, S50, S48 and S59 (see Fig. 4) were the only varieties which, under the conditions prevailing, had some potential value.

The area was mown, the herbage raked off and three weeks later (end of July) grazed by sheep. August was critically dry and, after a month, the site was badly dried up and all varieties were adversely affected. Red and meadow fescue (especially S53) retained the best colour, while in contrast S170, the timothies and white clover deteriorated badly. Productivity was very poor but Yorkshire fog stood out in a class of its own. Very little value could be put on the remainder of the varieties, except Danish red fescue and S53, the latter having retained an impressive amount of green vigorous leaf. The agronomic value of those varieties in group 3 was negligible.

After grazing on 3 September, RSMG, S50, dogstail, bent and ryegrass were readily picked out by their burnt appearance. Regrowth was slow but it was noteworthy that white clover was recovering and beginning to spread, though by 24 November, when the next observations were taken, it still contributed only 10% of the cover. Apart from those varieties placed in group 1, the value of the sown species in the autumn was unimpressive and for those in group 3 actually nil. S23 was clearly the outstanding grass, the value of S50 being somewhat impaired by its dry and wiry nature.

Discussion

The main features of the *Nardus* site were a combination of severe competition from the remnants of the original vegetation, particularly *Nardus*, and the adverse effects of the dry summer of 1959. Drought influenced the performance of the varieties on the thinner peat at this site more than on the *Molinia* area where soil moisture was apparently never seriously limiting. Sward development was slow in 1958, and in 1959 the drought interfered with continued progress and the performance was undoubtedly modified by the type of season.

The tendency to run to stem and the need for cattle grazing were greater at this site. Considering all factors, it is not surprising that fewer varieties were outstanding here than on the *Molinia* area. Only Yorkshire fog, S23 and S50 were prominent, though S24, S48 and red

fescue showed considerable potential at times. The performance of cocksfoot was poorer than expected and this is of greater interest when one considers the "high" position maintained by S53 under these conditions. Cocksfoot, timothy, red fescue, SSMG and dogstail were all more prominent on the *Molinia* site, but with regard to the mean performance on each area, ryegrass was much more important on the *Nardus* site where fog (valuable in both places) was important earlier in the sward history.

Results from early Welsh work (2, 8 and 9) make interesting comparisons with present data. Only a portion of this work was under oversowing conditions and many controversial points arise and will be dealt with overall in the general discussion at the end of the series. It is pertinent to note, however, that Davies (2), classifying varieties on the basis of their value for hill seeds mixtures, places in the first category, timothy, leafy cocksfoot, bent, fog, dogstail and red fescue. At the other extreme, meadow fescue, tall fescue and foxtail were put in the third-rate group.

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POPULATION-DENSITY STUDIES ON COOL-SEASON TURFGRASSES GROWN IN A SUBTROPICAL CLIMATE

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Five cool-season turfgrass mixtures were grown under two cutting heights and two nitrogen levels. Turfs were sampled for population density each spring and fall for a three-year period, using the core-sampling method. Densities of all declined steadily throughout the period in all treatments. With one exception, populations of any one species were at the same low level at the end of the study, regardless of the treatment.

INTRODUCTION

Most of the cool-season turfgrasses are poorly adapted to the southern California climate. Nevertheless, many acres of turf of these grasses are sown in the region every year. These turfs appear to lose density rapidly in most situations. Various management techniques have been proposed to prolong their life but have met with little success.

Many studies have been recorded on the effects of clipping and nitrogen fertilization on grass growth. Troughton (8) has reviewed these with particular reference to underground organs. Crider (1) observed that root growth stopped following the removal of 40% or more of the foliage: the more severe the clipping, the longer the period of root-growth stoppage. Harrison and Hodgson (3) found that in several cool-season grasses the total yield of foliage was reduced by clipping, the amount of reduction being directly proportional to the severity of the clipping. Stapledon and Milton (7) reported that tillering of *Dactylis glomerata* was reduced directly with the severity of clipping.

Most studies on nitrogen fertilization of grasses have shown that foliage growth is favoured by an excess of nitrogen, while root growth may be more extensive when nitrogen is limited (6, 8). The ratio of shoot weight to root weight may be increased by nitrogen fertilization (2, 5).

Studies were initiated in 1956 to determine whether certain clipping and nitrogen-fertilization treatments would prolong the life of cool-season turfgrass mixtures in the subtropical southern California climate.

MATERIALS AND METHODS

Five seed mixtures, approximating to commercial mixtures available at that time, were prepared and sown in a randomized-block design with four replications. The percentages shown are by weight of seed.

Mixture 1. Seeded at 3 lb. per 1000 sq. ft.
- 50% *Poa pratensis* (Merion)
- 25% *Festuca rubra* (Illahee)
- 25% *Agrostis tenuis* (Highland)

Mixture 2. Seeded at 3½ lb. per 1000 sq. ft.
- 40% *Poa pratensis*
- 15% *Festuca rubra* var. *commutata* (Chewings)
- 20% *Agrostis tenius* (Highland)
- 10% *Poa trivialis*
- 15% *Agrostis alba*

Mixture 3. Seeded at 4 lb. per 1000 sq. ft.
- 28% *Poa pratensis*
- 12% *Agrostis tenius* (Astoria)
- 30% *Festuca rubra* var. *commutata*
- 30% *Festuca elatior*

Mixture 4. Seeded at 5 lb. per 1000 sq. ft.
- 30% *Lolium perenne*
- 15% *Poa pratensis*
- 20% *Festuca rubra* (Illahee)

20% *Agrostis alba*
5% *Agrostis tenuis* (Highland)
10% *Trifolium repens*

Mixture 5. Seeded at 5 lb. per 1000 sq. ft.
80% *Festuca arundinacea* (Alta)
8% *Poa pratensis*
5% *Agrostis tenuis* (Astoria)
7% *Festuca rubra* (Illahee)

Individual plots were 96 sq. ft. in area and were separated by bare soil strips 1 foot wide. The entire area was fumigated with methyl bromide and seeded in December 1955. The following treatments were started on each mixture plot in April 1956, when all turfs were well established: (1) clipped weekly at 2 in. and fertilized with 1 lb. elemental nitrogen per month, a total of 12 lb. annually; (2) clipped weekly at 0·5 in. and fertilized with 1 lb. elemental nitrogen per month; (3) clipped weekly at 2 in. and fertilized with 1 lb. elemental nitrogen every 3 months, a total of 4 lb. annually; (4) clipped weekly at 0·5 in. and fertilized with 1 lb. elemental nitrogen every 3 months.

The entire experimental area was given phosphorus at 4 lb. and potassium at 6 lb. per 1000 sq. ft. at the time of seeding and annually thereafter. Nitrogen was applied as ammonium nitrate, phosphorus as single superphosphate and potassium as potassium chloride.

Irrigation was carefully controlled to maintain all plots at slightly below field capacity. Fungicides were used as needed to prevent disease, but no chemical control of weeds was practised.

Treatment sub-plots were sampled by the core-sampling method of Mahdi and Stoutemyer (4) each April and October, the first sampling being at the time treatments were

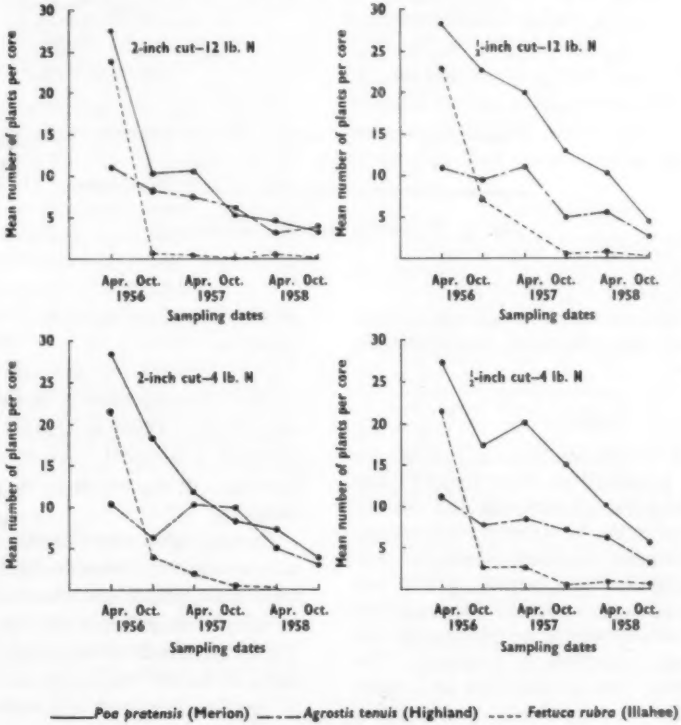
2-inch cut–12 lb. N
½-inch cut–12 lb. N
2-inch cut–4 lb. N
½-inch cut–4 lb. N
Mean number of plants per core
Apr. Oct. 1956 Apr. Oct. 1957 Apr. Oct. 1958
Sampling dates
Poa pratensis (Merion) Agrostis tenuis (Highland) Festuca rubra (Illahee)

Fig. 1. Population densities—Mixture No. 1.

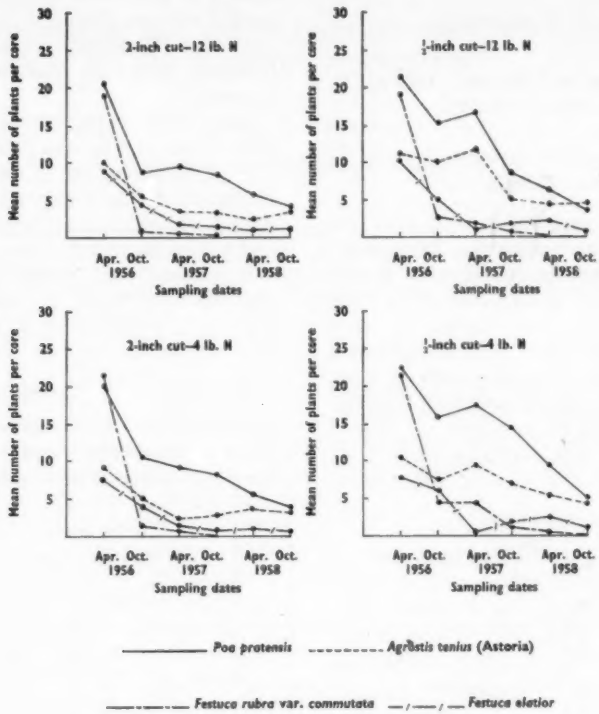

Fig. 2. Population densities—Mixture No. 3.

started. Six core samples were taken from each sub-plot at each date. The study was continued for three years.

RESULTS

The results of the studies on two of the mixtures are presented in Figs. 1 and 2. The other mixtures behaved similarly and are not tabulated. Population densities of every variety in every treatment declined more or less steadily throughout the period. With one exception, by the autumn of the third year the density of a variety was at approximately the same low level, regardless of treatment. The turfs were visibly thin at this time and weeds were invading, the principal weeds being *Oxalis corniculata*, *Cotula australis*, *Euphorbia supina*, *Digitaria sanguinalis* and *Cerastium viscosum*.

During the second summer a few scattered disease spots developed, caused by *Helminthsporium* spp. These were quickly controlled by applying a fungicide. Areas which had been diseased were avoided in all subsequent sampling.

Festuca rubra and *F. rubra* var. *commutata* were nearly eliminated during the first summer. Only a few plants of these species were found in samples taken after this time. None of the species increased to dominate the turf as the populations of the others decreased. Instead all species decreased in number, producing a thin open turf.

Agrostis tenuis, highland and Astoria strains, had a slower rate of decline than the other species. Surviving plants tended to form small patches, giving an uneven texture to the turf.

Poa pratensis, including Merion, appeared to maintain greater density during the first year under the 0·5 in. cut than under the 2 in. However, decline was rapid in the following summer and any benefit from the close clipping was quickly lost.

Festuca elatior in mixture No. 3 and *F. arundinacea* in mixture No. 5 formed coarse clumps. While *F. elatior* disappeared from the turf rapidly, the clumps of *F. arundinacea* persisted throughout the three years. The *F. arundinacea* population was significantly higher in the 2 in. cutting treatments than in the 0·5 in. at the end of the study period. This was the only species to respond to the treatments. *Lolium perenne* and *Agrostis alba* lost density at a rate comparable to that of *Poa pratensis* in all treatments.

DISCUSSION

These studies show that nitrogen fertilization and mowing practices may be of little value in prolonging the life of grasses which are not climatically adapted. Since all other requirements for good grass growth known to us were met and disease and insect pests controlled, lack of climatic adaptation appears to be the most likely cause of the decline.

Festuca arundinacea, the only species to show treatment effects, has been considered one of the cool-season grasses best adapted to this region. Experience has shown that the undesirable clumping of this grass can be overcome by using it alone and seeding it at extremely high rates, 6–10 lb. per 1000 sq. ft. A coarse but otherwise excellent turf of long life may be obtained in this way.

Until additional information is obtained from further study, the exact causes of the decline recorded can be only conjectured. The climate of the Los Angeles area would appear to be almost ideal for these grasses. Temperatures during most of the year appear favourable for good growth, extremes of temperature seldom being experienced. It may be that these grasses require more winter cold than they experience in southern California. This lack of cold might affect bud development and the breaking of bud dormancy. *Poa pratensis* turf in the inland desert region has been observed to grow well for many years. Very high summer- and low winter-temperatures are characteristic of these areas. This would also point to the lack of winter cold rather than to high summer temperatures as the cause of turf failure in the milder areas.

The steady thinning and weakening of these turfs indicate that these grasses in a subtropical climate may be unable to produce sufficient carbohydrates for maintenance and growth, and so eventually they starve. The environment in Los Angeles may produce a respiration rate exceeding the rate of photosynthesis over long periods for these grasses.

Whatever the physiological reactions may be, it appears doubtful from these studies whether simple management practices can be devised which will greatly prolong the life of these climatically unadapted grasses.

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THE CRUDE-PROTEIN CONTENT OF ITALIAN RYEGRASS

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The effects of variety, date of cutting flush growth and level of nitrogenous manuring on the crude-protein content of Italian ryegrass were studied on plots cut five times in 1958.

Raising the level of nitrogenous fertilizer from 174 lb. to 348 lb. N/acre reduced the percentage of dry matter from 0·5 to 2·0 and increased the percentage of crude protein in the dry matter from 0·9 to 5·1, with net increases in crude protein/fresh material of from 0·06 to 0·57%. Varieties showed consistent differences, the three Westerwolth types, New Zealand H.1 and New Zealand Italian being higher in percentage crude protein than Ayrshire, Irish, Danish and S22.

Cutting the flush growth earlier resulted in an increased percentage of crude protein for that particular cut, but no overall increase in mean crude-protein percentage.

INTRODUCTION

Italian ryegrass grown without an accompanying legume has a disappointingly low crude-protein content, even when lush and green. An experiment was set up at Auchincruive to compare the crude-protein contents of nine Italian ryegrass varieties on two cutting schedules at two levels of nitrogenous manuring.

EXPERIMENTAL METHODS

Statistical layout

A split-plot randomized block layout involving 108 plots each 8×1·5 yd. was chosen. The following treatments were replicated three times:

Main plots High nitrogen 4 cwt. nitro-chalk (15·5% N) per acre per cut

Low nitrogen 2 cwt. nitro-chalk (15·5% N) per acre per cut

Sub-plots. Nine varieties as listed in Table 2.

Sub-sub-plots. Flush growth cut on 22 May or 9 June.

Sowing and general manuring

Sowing took place under oats in April 1957. All plots were dressed with 4 cwt./acre superphosphate and 2 cwt./acre muriate of potash in spring 1958.

Sampling

The plots were cut with a motor scythe, leaving a stubble of 2–3 in., on the dates shown in Table 1. Second- and third-year data and more complete 1958 data are available (3). Yield data will be presented in a later paper.

Analysis

Duplicate 300g. sub-samples were dried at 98–100°C. Crude protein was determined on the milled dried material by a conventional macro-Kjeldahl procedure.

TABLE 1. Cutting programme and mean yields (tons/acre green matter)

Year	Cutting treatment		Cut No. 1	2	3	4	5
1958	Early 2nd cut	Date sampled	21 Apr.	22 May	8 July	3 Sept.	21 Oct.
		No. days' regrowth	—	31	47	57	48
		Yield	0·89	8·94	8·62	5·09	4·64
	Late 2nd cut	Date sampled	21 Apr.	9 June	8 July	3 Sept.	21 Oct.
		No. days' regrowth	—	49	29	57	48
		Yield	0·89	12·79	4·92	5·20	4·90

TABLE 2. Percentage of dry matter and of crude protein in dry matter, 1958

	Dry matter Cuts					Crude protein in dry matter Cuts				
	1	2	3	4	5	1	2	3	4	5
General mean (108)	21·0	17·9	18·7	24·6	12·3	24·6	11·7	11·8	9·4	19·8
High manuring (54)	20·0	16·9	17·8	24·3	11·7	27·0	13·2	13·0	9·9	20·9
Low manuring (54)	22·0	18·8	19·6	24·8	12·8	22·2	10·2	10·7	9·0	18·6
Early cutting (54)	21·0	16·6	21·2	24·2	12·3	24·6	14·1	9·1	9·6	19·9
Late cutting (54)		19·1	16·3	25·0	12·1		9·3	14·6	9·3	19·6
High manuring										
Early cutting (27)	20·0	15·4	20·1	24·3	11·7	27·0	15·9	10·3	9·9	21·3
Late cutting (27)		18·4	15·5	24·3	11·7		10·6	15·6	9·9	20·5
Low manuring										
Early cutting (27)	22·0	17·8	22·3	24·0	12·9	22·2	12·4	7·9	9·2	18·5
Late cutting (27)		19·7	16·9	25·6	12·8		8·0	13·5	8·7	18·8
Varieties										
Ayrshire (12)	19·3	18·2	18·8	24·2	12·5	23·3	10·4	11·1	8·8	19·2
Irish (12)	19·5	18·4	19·1	25·8	12·4	24·2	10·5	11·7	9·2	18·7
Danish (12)	20·1	18·1	18·5	23·5	12·5	22·5	10·7	11·2	9·1	19·0
New Zealand (12)	18·4	17·3	17·7	23·3	11·2	25·0	11·9	11·7	9·5	20·1
S22 (12)	20·0	17·9	19·3	23·4	12·5	23·2	11·2	11·7	9·4	19·6
H.1 (12)	20·1	18·3	19·0	23·1	12·0	25·1	10·8	11·9	9·5	19·4
Westerwolth (12)	24·5	17·6	18·7	26·0	13·0	25·7	13·2	12·8	11·1	21·6
Sceempter (12)	23·3	18·0	19·6	26·2	12·2	25·9	13·1	12·0	9·3	20·6
Mommersteeg (12)	22·6	16·9	17·9	25·5	12·0	26·5	13·6	12·4	9·1	20·1
L.D.S. 5%										
Manuring (M)	N.S.	0·50**	N.S.	N.S.	0·20**	3·27*	0·53***	0·62**	0·27**	1·44**
Cutting date (C)	—	0·47***	0·38***	0·43***	N.S.	—	0·33***	0·32***	N.S.	N.S.
Varieties (V)	1·86***	0·82**	0·76***	1·46***	0·45***	1·77***	0·87***	0·61***	0·65***	1·03***
Significant interactions	N.S.	MxC**	MxC*	MxC**	N.S.	MxV*	MxV*** MxX* VxC**	N.S.	N.S.	MxC*
C/V%	7·5%	6·8%	5·3%	4·5%	4·7%	6·1%	7·2%	7·0%	6·9%	5·9%

The bracketed figures indicate number of samples contributing to the mean in cuts 2, 3, 4 and 5. Half these quantities contributed to the mean of cut 1.

RESULTS

Percentage dry matter (% D.M.), Table 2

Doubling the nitrogenous fertilizer significantly reduced the % D.M. in cuts 2 and 5. The absence of significance in the other cuts was due to low main-plot replication. The reduction was most marked at cut 1 and least marked at cut 4. The older regrowths in cuts 2 and 3, as expected, had the higher % D.M. There were no significant differences in cuts 4 and 5 when regrowths of similar age were cut on the same date.

The significant manuring × cutting interaction in cut 2 showed a reduction in manuring response on delaying the cutting date from 22 May until 9 June, but in cut 3 the 47-day regrowth showed a higher response to manuring than the 29-day regrowth. Variety differences were significant at every cut, with no significant interactions. New Zealand ryegrass had the lowest % D.M. in cuts 1, 2, 3 and 5, whilst only New Zealand H.1 had a lower value at cut 4. The three Westerwolth varieties had high % D.M. in cuts 1 and 2.

Percentage crude protein (% C.P.), Table 2

Increasing the nitrogenous fertilizer raised the % C.P. significantly at all cuts and most markedly at the first cut. Only 2 out of 117 comparisons from the full data (3), both from cut 4, showed the opposite effect.

Common Westerwolth had the top % C.P. for cuts 3, 4 and 5, was second to Mommersteeg for cut 2 and third to Mommersteeg and Sceempter for cut 1. Ayrshire had the lowest % C.P. at cuts 2, 3 and 4 but Ayrshire, Danish, Irish and S22 were not significantly different at any cut. The responses to manuring of Ayrshire, Irish and Danish were generally low, and of the New Zealand varieties high. Thus, at cut 1, extra nitrogenous fertilizer raised the % C.P. of Ayrshire by 4·5 and of New Zealand by 8·3.

The older regrowths in cuts 2 and 3 had the lower % C.P., the fall in cut 2 being more marked at the higher level of manuring than at the lower level. There were no significant after-effects in cuts 4 and 5. The C.P. content of Westerwolth varieties fell significantly between 22 May and 9 June; Ayrshire, Danish, Irish and S22 did not fall so far. This difference arose from a wide range of variety means at 22 May and a lower range for the maturer regrowths.

Dry-matter and crude-protein contents were inversely associated. Thus, when crude protein is expressed in terms of the fresh material, there is a reduction in treatment differences. The mean for cut 1 was 5·2%. Cuts 2–5 gave means of 2·1%, 2·3%, 2·3% and 2·4% with a range over all treatments from 1·5 to 2·9%. The equivalent range of % C.P./D.M. was from 7·5 to 22·1%.

DISCUSSION

The low crude-protein contents of Italian ryegrass were confirmed, particularly when growth reached the bulk of which the species is capable. The variations may have been due to differences in leaf/stem ratio characteristic of the varieties or induced by the treatments, as established by Stapledon *et al.* (4). Although all three variables showed the possibility of statistically significant increases in the percentage of crude protein, the gains were not of much practical value. Taking the flush growth early resulted in a marked increase in percentage of crude protein, a drop in yield for that cut and a more uniform distribution of production throughout the year, but it had little effect on the mean crude-protein content for the year. It would be necessary to take more cuts per year, with a consequent reduction in the annual yield of dry matter, to achieve an increase in the mean percentage of crude protein.

Using a variety such as Westerwolth with a high percentage crude protein would be the cheapest way of realizing a high % C.P., but it is not capable of sustained production. A heavy dressing of fertilizer nitrogen would be the most costly way but would have the added advantage of raising the yield of dry matter.

Reductions in % D.M. and increases in % C.P. have frequently been noted, particularly in the American literature, during comparisons between the quality of nitrogen-fertilized grass and of legume/grass mixtures (5). Fisher

and Caldwell (1) working with Coastal Bermuda grass showed a rise from 7·9% to 14·1% C.P. and a fall from 41·7% to 29·3% D.M. from dressings to 1800 lb. N/acre.

Increased % C.P. is not necessarily an indication of improved feeding value, since the figure may include varying proportions of true protein and other nitrogenous compounds. Griffiths (2) has shown that there are important varietal differences in the nitrate content of ryegrasses. Washko and Marriott (5) showed that many grasses when given up to 300 lb. N/acre showed no reduction in feeding value, although contributors to the discussion of their paper quoted instances of reduced feeding value at the higher rates of N application.

This study has been presented in terms of crude-protein content because it is still the most widely used criterion of feeding value. It may well be that quality should be judged by digestibility and not by crude-protein content, particularly when dealing with a rapidly growing ryegrass.

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INTERNATIONAL DEVELOPMENT OF GRAZING AND FODDER RESOURCES

IX. JAPAN (SEQUEL)

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INTRODUCTION

The Food and Agriculture Organization of the United Nations has been rendering technical assistance to the Government of Japan since 1955, during which period the following specialists have visited the country in a series of annual assignments each of 4 to 8 weeks: 1955—R. O. Whyte, 1956—R. B. Tennent (under auspices of Government of New Zealand), 1957—R. O. Whyte, 1958—L. Corkill and P. D. Sears, 1959—W. V. Hadfield, 1960—R. O. Whyte, 1961—G. Maxwell Davies.

This article represents a sequel to the first article (1) in a series on Japan; it presents a summary of the advice given by the visiting specialists, a description of the progress achieved to date, and the probable future trend of developments. In 1960, I visited grassland improvement projects and farms in the following Prefectures: Fukushima, Tochigi, Gumma, Nagano, Kumamoto, Oita, Okayama and Tottori. Special attention was given to the development of improved pastures at high elevations, particularly on Asama, Kirigamine, Aso, Kuju, Hirusen and Taisen. Visits were also made to Kanto-Tosan Agricultural Experimental Station, Fukushima Livestock Breeding Station, and the National Institute of Agricultural Sciences in Tokyo and at Chiba.

CONTRIBUTORY FACTORS

Apart from the energetic action being taken by the Central and Prefectural Governments to promote pasture and fodder development, there are a number of contributory factors which are operating in varying degree to support what amounts to a major revolution in Japanese agriculture.

If the present policy of increased industrialization continues, particularly in more rural areas, it may be possible to visualize a reduction of 35 or 40% in that part of the population at present employed directly in agricultural production. Related to this is a current move to raise the limit on the size of holding in paddy areas, which is at present about 3 hectares. There is a marked increase in farm mechanization, particularly of small hand-operated equipment. The rice breeders have produced new types of their crop which mature in about 100 as compared with 150 days. Experiments are in progress to shift the period of rice transplantation. The removal of any support price for wheat and barley makes the cultivation of these winter crops uneconomic. There is considerable development to improve roads, although this does not yet affect the hill and mountain areas where access is at present so difficult. There are also important changes in dietary habits, particularly towards wheat bread, and the custom of, and taste for, drinking milk is being favoured by the provision of school milk.

If the size of holdings in paddy areas can be increased to, say, 10 hectares—still not too large for one family to operate with simple mechanical equipment, and yet large enough for properly integrated crop and livestock husbandry to be practised—conditions should be favourable for the cultivation of an increased acreage of short-term grass/legume leys or annual fodder crops in rotation. The

increased soil fertility arising from this integration will provide for higher yields of cash and food crops, so that the same return can be expected from a smaller acreage. This factor, combined with the use of the shorter-duration earlier-maturing varieties of rice and the falling demand for this cereal, will release more land over longer periods each year for the cultivation of pasture mixtures or fodder crops, even in winter in those parts of Japan where double cropping is possible. An example may be quoted:

	Yen per tan
Before	
Income from paddy	40,000
Income from winter crop of wheat or barley	10,000
Total	50,000
After	
Income from paddy	40,000
Income from fodder fed through dairy cows	50,000
Total	90,000

It is officially estimated that the total value of livestock production in Japan will in 10 years' time represent one-third of the total agricultural production, and will at that time be equivalent to the production from rice. If the present policy of pasture and fodder development is continued, and the various contributory factors continue to operate, there seems to be no reason why this objective should not be reached.

FUTURE TRENDS

Such excellent progress is being made in the establishment of seeds mixtures for sown pastures, which appears to be relatively easy in Japan, and such large areas are now coming under treatment that the problem of the correct place of improved pastures and their associated types of livestock production in the overall land-use pattern is becoming increasingly prominent. It is, therefore, gratifying to learn that a special group within the Ministry is studying the criteria for the classification of land for grassland improvement, while the complex matters relating to land tenure and rights of common grazing are also being reviewed.

These studies are of particular importance because most of the pasture development will be taking place in hill and mountain areas. Agreement has, therefore, to be obtained between rival forestry and livestock interests, and the need for soil and water conservation must be considered at all times. It is not desirable to clear protective wild grassland or secondary forest growth in the mountainous five-sixths of the country if the consequence is going to be serious damage to the remaining one-sixth in the valleys and plains.

In relation to the possible livestock development noted below, it may well be appropriate to consider some type of stratification of forms of pasture development and associated livestock husbandry in relation to altitude. On the one hand, distance from the village governs the type of animal production that can be contemplated, and on the other, the type, productivity and nutritional demands of different types of livestock govern the economic feasibility of the different types of, and costs involved in, pasture development. This point is elaborated further below.

The provision of feed for dairy cattle in the paddy areas has improved in recent years, although the small size of holding still necessitates stall feeding with cut fodders, and there is still too great a dependence on purchased concentrates. Farmers do not, however, appear to reduce the concentrate ration at periods when high-quality cut fodder is available (e.g., high-protein pure Ladino clover), nor do they appear to ration concentrates to individual cows in relation to their milk production. Obviously steps must be taken to reduce the costs of producing milk, and economy in concentrates would be an important contribution in this direction.

Distance from the village and difficulty of access still limit the use of improved upland pastures for grazing dairy cows. Pastures which have been costly to clear and establish are therefore grazed largely by the dry dairy stock and the mature and young animals of the indigenous red and black cattle. It is therefore difficult quickly to recover the expenditure on clearance and management. It would be preferable if the indigenous cattle

and dry stock could be kept at higher elevations on pastures which have been improved by less expensive methods.

It is suggested that those responsible for pasture improvement at medium elevations might, however, study the development of a co-operative grass farm and associated dairy unit in Oita Prefecture, Kyushu. This farm of 64 hectares is being established on the southern slopes of Mount Kuju (1788 m.), at an elevation of about 600 to 1000 m., by the Shirani Eastern Part Agricultural Production Co-operative Association. Pastures and fodder crops are being established on mechanically cleared and ploughed natural grassland. About 100 head of dairy cows are to be maintained there throughout the year, under the care of a farm manager, a machinist, two cattlemen and two farm labourers. The cattle will graze in summer and be stall-fed with conserved feeds in winter. It may be appropriate to design a special layout for the purpose, involving a milking parlour and a yard for holding and feeding. This co-operative approach and the maintenance of the dairy animals at higher elevations throughout the year might well be applicable in other parts of Kyushu and southern Honshu.

Now that pasture development for dairy production is proceeding satisfactorily, it seems desirable to consider the technical and economic possibilities of pasture development for the maintenance of beef cattle and sheep. Poultry pastures will not be considered here, although it is understood that there are important developments in this direction in certain districts.

Where it is not feasible to graze producing dairy cattle on high-grade improved pastures and so to obtain a maximum return on the investment, it may well be worth considering whether the fattening of beef cattle might not also be an economic proposition. The cattle that are at present available for this purpose are the so-called indigenous Japanese black and red breeds and also the male calves from the dairy breeds.

The indigenous breeds are kept by the farmers to provide draught power and stable manure, but they are also sold at various ages to the producers of Kobe beef. This process of rapid fattening in stalls over a period of about 3 months (live-weight increase about 500 gram per day) produces expensive beef which is supplied primarily to the luxury market—city restaurants and the like. It has been suggested that the rising standard of living and the changing dietary pattern may cause the demand for beef to rise to five times its present level, and customers may also require a less expensive article. The policy of milk from pasture has been so successful that it may be the time to consider the fattening of beef from pasture.

So far little or no use has been made of the males of the dairy breeds, which are sold in the first nine days after birth and made into sausages. The preliminary fattening trials of Jersey males being conducted in Okayama Prefecture should be extended to livestock farms in other parts of Japan, to discover whether it may be possible to utilize this potential resource. The use of beef bulls for artificial insemination of dairy cows might also be considered.

There therefore remain at present only the Japanese red and black cattle. Although these are regarded as beef breeds, preliminary data obtained from grazing trials on improved pastures in Kumamoto Prefecture in Kyushu indicated that the average live-weight gains of young steers on best quality pasture are only of the order of 300 gram per day. If, therefore, it is decided to establish a beef fattening industry on pastures, it would appear to be necessary to introduce for trial some animals of the recognized beef breeds of the world. It is probable that they would give a daily gain of from 750 gram up to 1 kg. per day, and so make beef fattening on pasture an economic method of using improved pastures at medium elevations which are not suitable for dairy cattle.

The grazing of sheep on natural pastures has not so far been successful, because of the unsuitable nature of the vegetation. Now that shorter artificial pastures can be produced so readily, it may be worth considering the introduction of sheep grazing on sown pastures, and the production of fat lambs as a means of

rapid economic return on the expenditure incurred in establishing these pastures. Mixed grazing of sheep with other types of livestock may provide for better utilization of a stand. Sheep combined with indigenous cattle may represent a useful treatment to promote the rapid improvement of natural pastures which have been disked and oversown with superior grasses and clovers. The cattle would eat and trample the coarse natural regeneration while the sheep would by their grazing, treading and manuring accelerate the spread of the sown species.

Turning now to management of sown pastures, this represents the most urgent problem of the moment. Too frequently one sees a good well-established sward at a high state of fertility, and with a good balance between legumes and grasses, being allowed to deteriorate in botanical composition and yield, due to lack of appreciation of some of the basic principles of management. The use of appropriate manures and fertilizers to swing the grass/legume balance in one direction or the other; the importance of controlled intensities of grazing at specific seasons of the year to promote or hinder growth of clover; the effect of the grazing of different types of livestock; the frequency with which one takes a cut for hay or silage and so swings the composition towards the taller, grassy species—all these require experimentation and demonstration. The balanced fertilizers provided by the industry are very good at the establishment stage, but the proportions of phosphate and nitrogen used in subsequent dressings deserve reconsideration.

It is necessary to repeat the recommendation made by Corkill and Sears (4) with regard to the fertility cycle—soil/plant/animal/soil—which is a fundamental part of the grazing system, and which makes it preferable to the cut-and-carry system whenever it is practicable. Some of the new settlers in the upland areas, particularly in Fukushima and Tochigi Prefectures, are practising an excellent form of ley farming, cashing in on the fertility acquired during the ley period and producing higher yields of their food and cash crops. Some of these farmers are in fact ahead of the experiment stations as far as this form of mixed farming or alternate husbandry is concerned. The clearing of new land and the establishment of sown pastures is, however, still rather costly (70,000 yen per hectare), even allowing for a 30 to 40% grant from Central and Prefectural Governments. Invasion of these and other cleared and ploughed areas in the hills and mountains by bracken, and in acid areas by *Azalea*, represents a serious problem.

Once again, one must refer to the still unsatisfactory position with regard to the varieties of herbage plants which are available. In 1960, the outstanding example of damage to the whole pasture development programme was provided by cocksfoot or orchard grass (*Dactylis glomerata*). This still remains the basic grass component of seeds mixtures in Japan (combined with Ladino clover), but the performance of 1960 sowings, both on farms and in high-altitude development projects, leaves everything to be desired. Cocksfoot seed from the United States of America, of no particular growth form, susceptible to rust in the humid Japanese summers at the higher altitudes, and with germination ranging from 33 to 50%, does not represent a good contribution to the pasture programme in Japan. The main responsibility rests with the Government, to ensure that the field officers, who do take such care with their preparatory stages, are given seed of adequate quality and known potential performance.

The interest that was expressed in other grasses for use in this programme deserves every support by those responsible for the introduction of new varieties for trial. *Festuca pratensis* and *Phleum pratense* (grazing type) might be worth considering. In the southern part of the country where the summers are hot or dry or both, attention should continue to be given to more heat-tolerant species, such as *Paspalum dilatatum*, or perhaps to special-purpose summer-fodder crops for feeding green until the more temperate pastures become productive again in the late summer. The ultimate objective should be the framing of pasture and fodder calendars for all the widely contrasting conditions of the country. These

will indicate what is available to feed the dairy or other cattle during each month of the year, and will inform the agronomist and the plant breeder of the lean periods which need to be filled by fodder conservation or by the provision of new crops or new varieties.

Stratification according to altitude

The following suggestions are made merely to provide a basis for discussion in connection with the place of pasture improvement in land-use planning, in relation to altitude, distance from village or town, and other factors. The suggestions apply more particularly to some of the sites visited in 1960 in southern Honshu and Kyushu, but they may be considered in relation to other parts of the country also. No mention is made of pigs and poultry, although it is recognized that these forms of animal husbandry are restricted to the farms in the zones recognized as plains, valleys and foothills.

As an alternative to this more or less static type of utilization, it might also be profitable to consider the system involving the seasonal movement of stock from low to high elevations practised in certain Swiss cantons. In this system, hay is made after the animals have moved to higher elevations, and the aftermath is grazed on the way down at the end of the season.

(a) *High altitudes*

Pasture improvement: Ploughing up, fertilizing, fencing and sowing of a limited area, say one tenth of the whole area being treated, to which cattle are admitted at appropriate intervals of about one week for short periods of grazing, to provide a high-protein ration as variety to the normal regime on the natural grassland. Natural grassland would be managed in the usual way to provide grazing and hay.

Livestock: Mature cows and young rearing stock of the indigenous breeds.

(b) *Medium to high altitudes*

Pasture improvement: Disking of natural vegetation, application of fertilizers, and oversowing with seeds of adapted strains of grasses and clovers (inoculated); elimination of regenerating natural species and promotion of sown species by controlled, but at first relatively heavy, grazing by mixed livestock, combined with fertilization. Area to be fenced to permit rotational grazing from the start.

Livestock: Indigenous cattle, combined where possible with sheep. Possibly also dry animals of dairy breeds from lowlands. Ultimately the stratum for the breeding and rearing of young stock of imported beef breeds.

(c) *Medium altitudes*

Pasture improvement: Ploughing up of whole area, fencing, fertilizing and sowing of seeds mixtures of adapted grasses and clovers. Subdivision into units for correct grazing control, with or without milking sheds or parlours and wintering quarters for the cattle. Facilities for harvesting and storing of hay and silage. Possible ultimate development of some form of crop rotation when pastures are ready to be ploughed up. A seed-potato industry has been suggested as a possible economic proposition at the higher altitudes, and this would be a good way of cashing in on the residual fertility of the grazed pastures.

Livestock: Dairy farming co-operatives on the Oita pattern. Dry stock farms for dairy breeds. Fattening of young indigenous animals for sale direct as beef, or to the Kobe beef-fattening industry. Ultimately the stratum at which to fatten imported beef breeds.

(d) *Foothills*

Pasture improvement: Similar to that suggested for medium altitudes; blocks to be improved by co-operative effort by farmers of the plains, or the complete integration of temporary leys into farming units of the type practised by the new settlers. Again, facilities in the co-operative blocks to be provided for fodder conservation and, to a limited extent only, for the cutting of green feed and its transport to the farms at lower elevations (bad examples of the results of continuous cutting and removal of green feed can be seen in many areas).

Livestock: Grazing of dairy cows, if within walking distance of the village, or if facilities are available for field milking and for the transport of the milk down to the collecting centres. Grazing of dairy cows on temporary leys in mixed farming enterprises, with stock controlled by tethering or electric fences.

(e) *Valleys and plains*

Pasture improvement: The small size of individual holdings limits the possibilities for sown pastures in paddy rotations. The present emphasis probably must remain on cultivated fodder crops or Ladino clover for cutting and feeding to stall-fed dairy cattle. The increase of the present ceiling would create conditions for ley farming comparable with those already existing in the foothill zone.

Livestock: Dairy cattle, and the indigenous animals required for draught and for the production of stable manure for the arable land.

RESEARCH

The research projects seen at the National Institute of Agricultural Sciences in Tokyo and at Chiba, at the Kanto-Tosan Agricultural Experiment at Nishinasuno, and at the Fukushima Livestock Breeding Station would appear to be on good practical lines, with the needs of the pasture improver well to the fore. Work on breeding, general crop improvement, varietal trials and seed production is now concentrated on the species of greatest potential value. Valuable studies of grazing management on natural wooded grassland and on natural grassland in process of improvement by disking and over-sowing are in progress. Studies on the soil relationships of pastures complete the ecological picture of soil/plant/animal. The reorganization and reorientation of work at Livestock Breeding Stations is also on the right lines, since it recognizes fully the need for research and demonstration on pasture and fodder development, as a basis for a healthy livestock industry. Provided grassland and fodder development is given its proper place in both agricultural and livestock stations, and the two aspects are sufficiently integrated, it may not be necessary to establish a research station specifically for grassland and fodder production, with the network of substations that would be necessarily involved.

Some of the agricultural and livestock stations have ample land for the establishment of pilot farms within their own boundaries. Such farms would provide excellent field laboratories in which the various specialists could try their new techniques and test their cultivars. The objective would be to evolve a fully integrated, highly productive and economic unit as a model and incentive to the local farmers, but, as one Director stated, his staff would find it very difficult to improve on the standards already achieved by these farmers.

SUMMARY OF EARLIER REPORTS

The first in the series of four FAO/ETAP Reports (2) was primarily a statement of the position at the beginning of the project, with special reference to land utilization, the natural vegetation and ecology of the grassland types, and the establishment of artificial grasslands. Tentative recommendations were made that the Central Government should begin studies on the practical aspects of pasture and fodder development, as a basis for the rapidly developing dairy industry, supported by more fundamental work on plant introduction, soils, nodule-bacteria relations of legumes, and the chemical composition and digestibility of indigenous and exotic species. It was stressed that training of grassland development officers was urgent, both within the country and overseas.

The second report in the FAO/ETAP series (3) relating to the 1957 assignment referred again to the place of grassland improvement in the overall land-use plan, and stressed that the five-sixths of the land represented by hills and mountains must be developed with great care so as to avoid damage to the remaining one-sixth of the land; the valleys and plains contain most of the valuable cropland. Land classification based on land capability in relation to measurements of run-off and soil loss from different types of natural and artificial covers was therefore recommended. Comparisons were recommended between the "cut and carry" and grazing systems of pasture utilization, with reference to Japanese conditions of land tenure and other special factors. It was suggested that co-operative pastures at the higher elevations might be tried. The Government should consider the granting of credits for land clearance and pasture establishment. Greater control of the types of herbage and fodder cultivars was recommended, as well as exploratory selection and breeding based on the local naturalized types. Breeding of indigenous pasture species should be discontinued. The importance of studies of volcanic ash and other

soil types and of the legume/bacteria relationship was again stressed. A need was noted for more team work both in Agricultural Research Institutes and in the Prefectures, for more contact between research and field workers and for more interchange of experience between Prefectures. Group training of extension officers and the holding of special courses in pasture management and fodder production in Universities and Agricultural Colleges were recommended.

The Report of the 1958 assignment by Dr. L. Corkill and Dr. P. D. Sears (4) again referred to the large grassland potential of Japan, and stated that full encouragement should be given to the technical, extension and economic services necessary for its realization. Research workers should be more conversant with the soil/pasture/animal/soil cycle of growth and utilization, and relevant literature should be translated into Japanese. Investigations should be directed towards a full understanding of the growth and utilization of the most suitable strains of the herbage species known to be adapted to the different ecological conditions. Steps should be taken to ensure that imported seed is of strains of known performance in Japan. Strains from both within Japan and from overseas should be collected and tested under typical regional conditions, and the most suitable should be multiplied under official supervision. Breeding institutions should be located in the three main regions. Seed yields could be improved by limiting seed production to the most favourable regions and by improving techniques, including greater use of fertilizers and of defoliants immediately before harvesting. The certification scheme relating to the main farm crops should be extended to cover herbage plants. Conservation of fodder should be studied, especially the making of hay from high producing pasture. The best methods of composting and of utilization of dung and urine should be studied. The prevention and control of bloat requires further study. The potential of high-producing pastures to conserve soil and water should be compared with those of other plant covers and the results integrated to other types of land utilization, based upon a properly designed system of land classification.

The recommendations made as a result of the assignment by W. V. Hadfield in 1959 may be summarized as follows (5):

Economic:

(a) Investigation of economy of milk production at a reduced level of concentrate feeding.

(b) Investigation of ways and means of reducing the retail price of milk.

Land reclamation:

(a) Ploughing compared with discing.

(b) Use of the fallow after ploughing of native sward.

(c) Use of tine harrows and rollers for final seedbed preparation.

(d) Experiment with giant discs for surface working before ploughing and for cultivation of hill soils too steep for the plough.

(e) Use of pioneer crops.

(f) Full-scale trials to discover the best methods of introducing grasses and legumes into the native swards.

(g) Use of the combine drill for sowing seed.

Strain testing and studies of pasture composition:

(a) Systematic approach to plant introduction and strain testing.

(b) Use of perennial ryegrass to replace Italian ryegrass in grazing pastures.

(c) Greater use of timothy in grazing mixtures.

(d) Experiment with rates of seeding and different combinations of grasses and legumes for grazing pastures.

(e) Trials with combinations of grazing and hay strains of grasses and legumes.

Management:

(a) Investigation of effect on yield and composition of pasture with different levels and at different frequencies of cutting.

(b) Yields of grasses and legumes under cutting system when grown in rows and broadcast both with and without companion species.

(c) Comparison of grassland yields under cutting and grazing.

(d) Fertilizer trials on different soil types.

Seed production:

Seed certification system for production of seed of improved and bred strains and those imported strains intended for seed production.

Extension and experimentation:

(a) Investigation of practicability of training extension officers in grassland husbandry.

(b) Co-operative grassland experiments involving both grassland officers and research officers.

It will be seen that these four reports followed very similar lines, and that there was general agreement among the specialists concerned as to the lines to be followed in pasture development in Japan. The recommendations in these Reports were translated into Japanese by the Ministry of Agriculture and Forestry in Tokyo and circulated to Experiment Stations, Livestock Farms and Prefectural Governments. It is extremely gratifying to see the extent to which the advice of these F.A.O. experts has been acted upon, and the momentum which the programme has now achieved. Where in 1955 it was difficult sometimes to find any grassland officers in Prefectural Governments, now, in 1960, the seminar held at the end of field tours in an individual Prefecture was attended by some 20 or 30 specialists actively concerned and well experienced in one or other aspect of the subject. F.A.O. and the Government of New Zealand should feel proud to have been associated with such an active and dynamic programme.

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INTRA-VARIETY VARIATION IN RHODES GRASS (*CHLORIS GAYANA* KUNTH) IN KENYA*

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Considerable plant-to-plant variation has been observed in ten varieties of Rhodes grass in Kenya. Progenies of single plants of one diploid and two tetraploid varieties showed similar variations, thus suggesting sexual xenogamous reproduction.

Rhodes grass is an important ley grass in Kenya and considerable attention is being given to this species at the Kitale Grassland Research Station, where over 100 samples, mostly of local origin, have been tested. Some of the best of these have been introduced into cultivation on a commercial scale, and it was thought that these selected types might be improved still further. The first step in this direction was to find out whether our best varieties consist of uniform plants, or whether there is plant-to-plant variation which could provide a basis for selection and improvement. To answer this question a study of variability in Rhodes grass was undertaken in 1958. As Rhodes grass has a stoloniferous habit a separate plot was allocated to each plant, grown from a single seed. The seeds were sown in small peat pots and after about 6 weeks the seedlings were transplanted to plots 3×6 ft., separated by 2-ft. paths. The stolons soon reached the plot limits and were trimmed repeatedly to prevent mixing.

In 1958, 1959, and 1960, 1230 single-plant plots of the following ten varieties were established:

K 50198	Nzoia (Kenya)	291 plants
K 5611	Mpwapwa (Tanganyika)	254 ,,
K 53166	Mbarara (Uganda)	276 ,,
K 50193	Masaba (Kenya)	60 ,,
K 5752	Ixopo (S. Africa)	108 ,,
K 51426	Chepararia (Kenya)	39 ,,
K 59192	Katambora (Rhodesia)	21 ,,
K 57168	West Suk (Kenya)	75 ,,
K 57163	Kerio Valley (Kenya)	64 ,,
K 53728	Nyanza (Kenya)	42 ,,

The majority of varieties under trial showed remarkable plant-to-plant variation and many characters, both morphological and agronomical, were involved, although the general type was usually maintained; for example, most plants of the Mpwapwa variety were robust, with thick stems and broad leaves, and had long awns on the spikelets; plants of the Nzoia variety had characteristic leaves, and short thick racemes on the panicle; most plants of the Mbarara variety had narrow leaves and thin racemes. Some variation was noticeable even at an early, pre-flowering stage. Thus, the stolons varied in thickness and in the length of their internodes; also in their

*In his covering letter of 15 April 1961 forwarding this article, the author wrote as follows: 'In the March 1961 issue of the Journal there is a paper by E. M. Hutton on the inter-variety variation in Rhodes grass. This paper contains very useful information and is of particular interest to us. There is, however, one important difference in the results obtained by Dr. Hutton and our observations at Kitale. While in Dr. Hutton's trials "no obvious plant-to-plant variation in the morphological characters of any variety was noted", all our varieties under trial showed very considerable intra-varietal variation. These differences in the behaviour of our varieties and Dr. Hutton's imply different modes of reproduction and different methods of selection and breeding. In view of this I think it would be of interest for those working with Rhodes grass to compare our conflicting results and this may perhaps stimulate a further study of more material and under different conditions. I have, therefore, written this brief account of our results.' *Editor.*

speed of growth. The density of cover and the width of leaves also varied. In the Nzoia and Mpwapwa varieties a few plants had practically no stolons and formed loose tufts. At the flowering stage the plant-to-plant variation became even more evident, and within the same variety the individual plants varied in the height of flowering stems, in leafiness, in the density of stands, in the size, shape and colour of racemes, and in several other characters, sometimes minor but clearly distinct. Katambora and Ixopo varieties, especially the former, showed less variation than the others, and in Katambora about 75% of plants were almost identical.

In the first year all plants were allowed to flower and to form seed, and the time of mass flowering and seed ripening varied very considerably. In the next years the plots were repeatedly clipped at the grazing stage to imitate grazing. The Katambora, Chepararia, and Nyanza varieties were not studied under clipping treatment as they were first sown in 1960. Under clipping treatment the plants within each variety varied considerably in vigour, speed of recovery after clipping, sward density, time of appearance of the flowering stems and their density and persistence; also in susceptibility to a *Helminthosporium* leaf disease—an important feature, especially for the Nzoia variety.

This considerable variation within Rhodes grass varieties observed at Kitale does not conform with the results obtained at Brisbane by E. M. Hutton (3) who states that "no obvious plant-to-plant variation in the morphological characters of any variety was noted". In view of this discrepancy, which may be due to differences in climatic and other environmental conditions, or to a different set of varieties under trial, it has been decided to publish this short interim report before the completion of our variability trials.

The variations observed at Kitale support the possibility of selection within a variety and raise the question of the inheritance of variations and of the mode of reproduction of Rhodes grass. The bagging of a few flowering heads at Kitale (1) suggested the occurrence of cross-fertilization, but on the other hand there is a statement by Brown and Emery (2) that tetraploid varieties of Rhodes grass are apomictic, although diploid types may be sexual. To clarify the position, seeds from a single panicle of a few morphologically distinct plants of three varieties were sown in single-plant plots: 145 seeds of 5 plants of the Nzoia variety, 123 seeds of 4 plants of the Mpwapwa variety, and 83 seeds of 3 plants of the Mbarara variety. The progenies of each single plant again showed considerable plant-to-plant variation, in most cases almost to the same degree as in plants grown from a random sample. Only the progenies of two plants of the Nzoia variety showed a prevalence of the mother type, though some variations, mostly of minor morphological character, were also noted. Judging by the behaviour of single-plant progenies at Kitale, Kenya, certain varieties of Rhodes grass, at least, can be regarded for all practical purposes as cross-fertilized, xenogamous plants. If Rhodes grass were an apomict a complete, or high, degree of uniformity in the progenies of single plants could be expected. No embryological or detailed cytological studies were undertaken. However, chromosome counts of four varieties were carried out for us by D. N. Singh of Queen Mary's College, University of London, whose help is gratefully acknowledged. The chromosome numbers found by him were $2n=20$ for the Nzoia and Katambora varieties and $2n=40$ for the Mpwapwa and Mbarara varieties, implying that in our progeny tests both diploid and tetraploid forms behaved as sexual, xenogamous plants.

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REPORT ON A TOUR IN NORTHERN FRANCE FROM 22–27 MAY, 1961

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This description of grassland husbandry was written after a week's tour in northern France by 36 members of the British Grassland Society, who visited commercial farms in north-east Brittany, Normandy and Champagne. Visits were also paid to the Central Plant Breeding Station at the National Centre of Agricultural Research, Versailles, and to the Agricultural Schools at Grignon (near Versailles) and Pixerecourt (near Nancy in Lorraine). The details of grassland techniques, etc., given in this account, apply specifically to these regions.

The tour began in Brittany where many of the soils are sandy, acid and inherently low in fertility. They sometimes lie on a clay subsoil, which can give rise to drainage problems: rainfall varies from approximately 28 to 40 in. Large areas of Normandy, which were visited next, are covered by a loamy mixture of clay and sand lying on a calcareous sub-soil. The climate is generally drier than in Brittany and the rainfall varies from 30 in. in the west to approximately 20 in. in the east, where the general conditions appear similar to those of East Anglia. In Champagne calcareous soils are again predominant; annual rainfall is just above 20 in. and summer droughts frequently occur. Calcareous soils and oolitic limestone hills occur throughout Lorraine, where the rainfall approaches 30 in.

French agriculture was in a relatively unproductive state until the eighteenth century, but following the French Revolution there was a marked increase in the landowning peasantry. Although agriculture has been partly protected by government measures, increasing competition from industry since 1860 has caused the proportion of the population engaged in agriculture to fall from 48 to 25%. Arable land decreased from 64 million acres in 1892 to 48 million in 1957, while permanent pasture increased from 15 to 33 million acres. It is generally considered by the Advisory Service that the minimum size for an economic agricultural unit (not engaged in the production of specialist crops such as vegetables or wine) is now 60–90 acres. However, as the following figures show, the majority of French farms are run as small enterprises, 80% of the total number being worked solely by family labour, and there are few larger farms:

Farms of less than 25 acres	4,500,000
,, 25–125 acres	700,000
,, 125–750 acres	100,000

At the moment, competition from industry, the better social facilities for industrial workers, and lack of centralized marketing systems are all leading to a reduction in the numbers of farmers.

GRASSLAND TECHNIQUES

Permanent pasture occupies a large area of northern France; much of it appears botanically poor and not well managed. Since the last war the value of alternate husbandry has been recognized and it is now being actively recommended.

Pasture establishment and seeds mixtures

Alternate husbandry is based primarily on 3- to 4-year leys. Direct reseeding is strongly recommended for long leys and undersowing is actively discouraged. Italian ryegrass is not normally incorporated as a constituent in long-ley mixtures because of its depressing effect on the more persistent grasses. Seeds are sown at from 10 lb. per acre of perennial ryegrass to 20 to 25 lb. of meadow- and tall-fescue: only 1 lb. per acre of white clover is

sown. Lucerne is sown at 8–10 lb. per acre in mixtures and at 15–20 lb. if alone.

Emphasis is placed on simple mixtures of one grass/one legume and on the selection of the correct varieties, particularly in relation to earliness. The perennial ryegrass/clover ley was originally the most popular, particularly in the wetter areas of Brittany and West Normandy. Because of apparent lack of productivity during droughts, this mixture has been losing ground in favour of leys based on cocksfoot, lucerne and tall fescue.

Mixtures consisting chiefly of maize are grown for summer fodder production and kale is becoming increasingly popular. Red and crimson clover are still grown alone, but more frequently with Italian ryegrass. Rape is being replaced by fodder mixtures of vetches and cereals or Italian ryegrass.

Many useful herbage varieties have been produced in recent years; the following varieties appear to be particularly interesting:

(1) *Tall fescue:* '*Manade*'

Considered to be at least 10–15 days earlier in the first spring growth and in flowering than S170.

(2) *Hybrid Italian:* '*Io*'

Stated to be as early as HI under French conditions, but more winter hardy and approaching perennial ryegrass in persistency.

(3) *Italian ryegrass:* '*Rina*'

A leafy, persistent type which is generally considered to be superior to Rita.

(4) *Cocksfoot:* '*Germinal*' *and* '*Floreal*'

Both of these are leafy types and are stated to be appreciably earlier than any 'S' variety of cocksfoot.

In order to obtain a continuity of first grazings during early spring, four mixtures would normally be recommended for any particular farm. Typically one mixture would be selected from each of the following categories:

(1) Manade tall fescue/white clover;
Germinal cocksfoot/white clover

(2) Floreal cocksfoot/white clover;
S215 or Naiadi meadow fescue/white clover

(3) Lucerne with either Prairial, Taurus, S26 or S143 cocksfoot (sown in alternate close drills)

(4) Late perennial ryegrass/white clover (e.g. Melle or S23 ryegrass);
Timothy/white clover.

In addition swards of Italian ryegrass, with or without red clover, are often recommended for additional flexibility in management.

Grassland management

The use of electric fencing or paddock grazing is generally associated with ley farming. It is recommended that each sward should be grazed during the late spring when the flowering apex is approximately 3 to 4 in. high. This removes the flowering shoot and encourages fresh leaf production. After the first grazing in the spring, farmers are recommended by technical advisers to graze perennial and Italian ryegrass every 4–5 weeks, timothy/meadow fescue and tall fescue every 5–6 weeks and cocksfoot and lucerne every 6 weeks.

At the time of the visit (the end of May) many of the swards were being grazed when in flower. This was partly a result of the season, which had caused a considerable growth of grass in May, and partly because of the farmers' reluctance to graze their pastures hard for fear of drought later in the summer. The stock were not generally forced to clear off all the herbage; the residue was topped. Insurance against drought is obviously one of the major points dominating the planning of grassland management and is one of the reasons for the popularity of tall fescue, cocksfoot and lucerne. Spring-sown Italian ryegrass was not generally used for production during drought periods as the springs are often too dry to guarantee a sufficiently good establishment.

Conservation is primarily based on haymaking. Low-density baling is now practised.

Barn hay-drying has recently been introduced, but so far has not been widely adopted. Silage making is not popular, although some good maize silage was seen. Advisers recommend that grass should be wilted for 2–3 hours before ensiling and additives are used (AIV or formic acid or molasses). The wider use of silage would probably benefit grassland husbandry as a whole by giving greater flexibility in management during early May.

Fertilizer nitrogen is considered more reliable than legume nitrogen; up to 200 lb. of nitrogen per acre are applied in 4 to 5 dressings during the year. Even on grass/lucerne swards, frequent dressings of nitrogen are recommended, so that after the second harvest year the contribution from lucerne declines. The hard winters and dry summers probably account for the lack of enthusiasm for white clover. The application of phosphate and potash is varied to suit circumstances. At the moment there is considerable scope for their use, as much of the land being brought into alternate husbandry is low in both nutrients. There is no Government subsidy for the purchase of fertilizers. The price of nitrogen varies from 10d. to 1s. 2d. per lb., depending upon the type of fertilizer. P_2O_5 and K_2O cost about 10d. per lb. There is a Government subsidy of 30 to 40% towards the cost of lime as applied.

Grass-seed production

The consumption of grass seed is approximately 10,000 metric tons per year. Perennial ryegrass accounts for most of this, followed by cocksfoot, Italian ryegrass, meadow- and tall-fescue and timothy. In 1960 France produced 6% of its own seed requirements (15% of the cocksfoot). The authorities aim to import only good varieties of grasses grown under controlled certification schemes. At the moment the demand is greater than the supply and uncertified seed has to be imported to make up the deficit. There appears to be a definite market for good quality seed of the right varieties, e.g. S170 tall fescue.

Livestock production

In pure beef herds single suckling is practised. Other calves are generally bucket fed; they receive whole milk for 2 or 3 days and milk substitute with some concentrates for the next 12 weeks. They are generally put out to graze during the summer, as soon as possible after reaching 3 months of age. A typical rearing programme for calves born during autumn and winter is: first summer—grazing; second winter—cheap fodder feeds; second summer—grazing; third winter—fodder plus concentrates. In their third winter they are either being milked or fattened. Heifers are generally reared at a higher plane of feeding than steers so that they can calve at 2 years of age. In several cases, Normandy cows, which had calved during the autumn, achieved maintenance and 2 to 3 gallons of milk per day from cocksfoot, which was in flower. This relatively high production from such swards may have been due to the fact that the stock were not forced to graze the herbage very tightly so that a high degree of selection was possible. In addition, the intense sunshine and rapid growth of the grasses during May may have produced a higher quality herbage than is normally experienced at this stage of growth in Britain.

Many Charollais and Charollais crosses were seen during the tour. They appeared to be of two types: one heavy- and one light-boned. The latter seem to be the more desirable for importation to Britain. It was stated that Charollais beef animals may gain 2 to 3 lb. of liveweight per day in summer on grass and 1½ lb. per day in winter on silage. They are normally expected to be fat when 2 to 3 years old at 13 cwt. liveweight. Apparently the progeny of Charollais crosses must be fed particularly well during their first three months. If fed on milk substitute, with little or no milk, they do not generally make sufficient progress.

In France pure-bred Charollais cattle are unquestionably the most popular with butchers because of their higher percentage of lean meat, their low percentage of bone and fat and the high percentage of valuable cuts of meat

which they yield. The value of Charollais meat is indicated by the fact that of the 5 meat grades the top grade is reserved for pure Charollais cattle.

Very few sheep were seen on the farms visited and generally in this part of France they were herded by day and housed by night or housed indoors. Both these practices may result from the lack of adequate fencing and water.

Several interesting facets of animal production emerged. Firstly, there is no Milk Marketing Board as in the United Kingdom, but it is estimated that 50 to 60% of the milk is sold through milk societies or co-operatives. There is some variation between districts in milk prices and these are fixed by the government to give a 10% variation within a district, depending upon season and also on whether milk is to be used for liquid consumption or for manufacture.

There is no fixed price for beef, but it is controlled indirectly by SIBEV (Societé d'Intervention sur le Marché du Bétail et de la Viande). This is a Ministry Commission which is continually in operation and buys surplus meat from the markets if the supply is too great. This meat is then stored by refrigeration and gradually released to the market. In order to provide the money for this operation, a 2% tax, paid by the butcher at the abattoir, is imposed on all meat sold.

A slaughter policy to control foot and mouth disease has been established in the east of France around Nancy, in Brittany and in certain districts of Normandy. It is planned to extend it to the whole of France in the next few years. Cattle in all other areas must be inoculated once per year against foot and mouth disease. Part of the cost of this is borne by the farmer. To be certain of controlling foot and mouth disease, stock need to be inoculated twice a year.

Milch cows must be free of mastitis, T.B. and brucellus abortion: beef cattle are tested for T.B. before and after slaughter.

ADVISORY SERVICES

There appeared to be two principal Advisory Services: there is an official service, which is free; and in addition an organization known as C.E.T.A. which was established by Government decree in April 1959. Under the C.E.T.A. scheme a number of farmers group together to pay part of the remuneration of an Advisory Officer, each farmer paying from 3/– to 20/– per acre per annum. Part of the cost of this scheme is borne by the State. In order to keep these Advisory Officers up-to-date with the latest techniques, there are specialist officers who maintain contact between Research Institutes and the general officers (both ministry- and group-employed). These liaison officers may be paid solely by the Ministry or may receive part of their salary from trade sources.

The general impression which was obtained during the visit was that as far as grassland farming is concerned there is great enthusiasm for development and much progress is being made. However, the Farm Improvement Schemes in Britain have resulted in better fencing, water supplies and buildings. These assets, and also the fact that British farms are generally larger, should enable British farmers to compete more effectively in livestock production from grass.

The thanks of the British Grassland Society are due to the President of the French Grassland Society and all his colleagues for their most valuable help and assistance in organizing this tour.

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GRASSLAND RESEARCH INSTITUTE. 1961. **Research techniques in use at the Grassland Research Institute, Hurley.** *Bull. 45 Commonw. Bur. Past. Fld Crops* pp. 167, bibl. 127, illus., Farnham Royal: Commonw. Agric. Bureaux. 40*s*.

The central problem which confronts the grassland worker is the assessment of potential grassland yield in terms of animal products. He requires a knowledge both of the response of the sward itself to local conditions of soil, climate and management and of the nutritive value of the herbage in producing meat, milk or wool. The development of reliable experimental techniques at both these stages is, however, laborious and time-consuming, and the present account of those in use at the Grassland Research Institute, Hurley, is therefore particularly welcome.

The book begins with a review of the problems of experimental design and interpretation posed by the grass crop, and throughout special attention is paid to the lay-out of field plots and the techniques of sampling, both at the research station and in extension trials. An account is then given of the methods used for herbage assessment, including details of physiological studies in the glasshouse and growth room, and a critical review of the cutting and grazing techniques used in the measurement of herbage and seed production in the sward. This chapter concludes with an account of the botanical analysis and classification of pastures, while the after-effects of the ley on the root weight and organic-matter content of the soil, and on the yield of subsequent arable crops, are dealt with in a later section.

The grassland sward is, however, only the first step in animal production, and it is gratifying to find a large part of the book devoted to the problems of animal assessment. The nutritive value of the sward is determined both by the digestibility of the herbage and by the amount taken in by the animal, and techniques for measuring both these components are critically discussed. The significance of the type of stock and the stage of the life-cycle is emphasized, while the importance of using worm-free stocks in nutritional experiments and the value of twins or half-sibs in reducing genetic variability are also stressed. One would, however, like more information on the assessment of herbage using the dairy cow; this might show a different picture from that given by sheep and beef cattle.

The book concludes with an account of the sampling and preparation of material for chemical analysis, and the special laboratory equipment used in this work. With the present emphasis on the nutritive value of herbage, this section might have been extended to cover the analysis of such important components as digestibility and soluble carbohydrate content; such analytical techniques could well form the subject of a later volume.

A subject index, in addition to the summary of contents, might have enhanced the ease of reference, but this is a minor criticism of a most valuable handbook which should be in the hands of every grassland research worker. The experimental techniques described here should save the beginner years of trial and error, while even the experienced agronomist can learn much from them.

J. P. COOPER.

M.A.F.F. **Silage making and feeding.** *Bull. 37 Minist. Agric. Fish. Fd* 1961, pp. 43, illus., London: H.M.S.O., 3*s*. 6*d*.

This Bulletin, which has been completely rewritten, is a most useful and readable account of modern techniques in silage making, mechanization and feeding. Information on the construction of silos, cutting and handling the crop, methods of controlled- or self-feeding and silage rations should be of real help to the newcomer to silage-making; to the old hand it should be most interesting to read this new edition of Bulletin 37 alongside the previous 7th Edition, published in 1956, as a record of progress and changes in the last five years. The most impressive advance has of course been made in mechanization; it is perhaps difficult to believe that the flail harvester was not even mentioned in 1956, at which time the buckrake was still the main piece of harvesting equipment. Only brief mention was then made of the advantages of wilting the crop. This is discussed in much fuller detail in the present edition, although one of the main benefits of wilting, namely the production of silage of which animals will eat large amounts, is not considered. Why animals should eat more silage of high dry matter content is not known; and this is only one aspect of our serious lack of knowledge on the feeding value of this conserved feed. This lack is brought home forcibly by the continued use in the present Bulletin of crude protein content of silage as the main index of its nutritive value; one must hope that before the 9th edition appears some system based on type of crop and date of cutting (the latter is the basis of a very successful forage evaluation system used in the Eastern U.S.A.) will have been adopted, both for evaluation and as a guide as to what to grow and when to cut for different classes of animal production. Undoubtedly the silage rations suggested are a reasonable guide to feeding, but it does seem likely that even more precise rationing of 'roughages', demanding much more exact knowledge of nutritive values, will be necessary in the more competitive livestock feeding that we face.

Other differences between the two editions are of real interest. Sodium metabisulphate had a 2-page appendix in 1956, but only a half-paragraph in 1961, which indicates how little this additive has lived up to expectations. Little space is now devoted to crops for ensilage, as it is concluded that grassland is the cheapest crop. It is surprising, however, that fodder maize, which had

nearly two pages in the earlier edition, when the new hybrids were only under test, has only four unenthusiastic lines in 1961, when several thousand acres of these hybrids are being grown.

Finally, in Table 9 in the new edition, the starch equivalent values of the three grades of silage are all given a probable feeding value 5 units of starch equivalent higher than in the 1956 edition—an encouraging sign of confidence by the authors of this most informative Bulletin! W. F. RAYMOND.

RATTRAY, J. M. **The grass cover of Africa.** *FAO Agric. Studies No. 49*, 1960, pp. 168, with coloured map of Africa on scale 1: 10,000,000, bibl. 164, 23 × 15·5 cm., Rome, Food and Agriculture Organization of the United Nations, 12*s.* 6*d.* or $2·50. Also in French and Spanish editions.

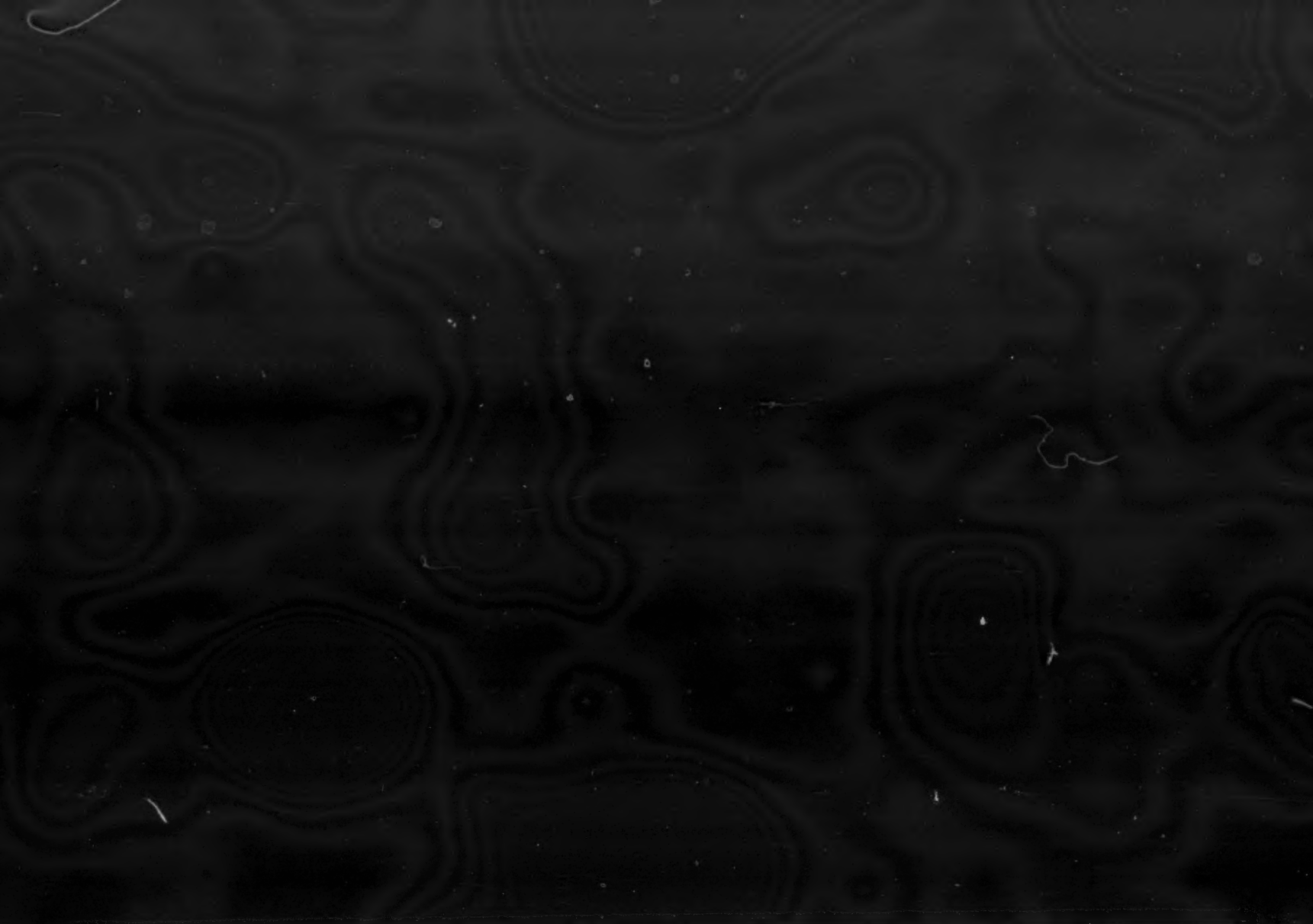
The approach to mapping of vegetation used in this publication is largely a novel one and is aimed primarily at providing a general guide to the pastoral resources of Africa. The emphasis is on utilization and there is no doubt that the natural grass cover is, and will most likely remain, at least for a long time to come, of fundamental importance to livestock production and hence to the economy of this continent. The map will be of value to those concerned with ecology of pastures, phytogeography and agricultural planning on broad lines. The author has brought together a large amount of scattered information, varying greatly in degree of detail from place to place, and it must have been no easy task to piece this together in the form required for presentation. In the book accompanying the map the text is divided into 6 chapters. Chapter 1 deals with ecological relationships of the grass cover and discusses the basis on which the various zones are demarcated. Chapter 2 explains the method of presentation of the map, where "the emphasis is placed first on the main grass associations, characterized by a particular genus, and secondly on the type of vegetation with which they are commonly found". Thus a specific colour is allocated to the dominant or characteristic grass genus, while different types of hatching are superimposed to indicate the physiognomic formations, namely, woodland, savanna, steppe, shrub steppe, desert or grassland. Further subdivision is effected by a series of numbers following the initial letter of the type genus, thus H1, H2 . . . H41 for different communities of grasses in which *Hyparrhenia* is the dominant or characteristic genus. In Chapter 3 there is a brief presentation of the types of vegetation with which the grass cover is associated, followed by a short discussion of successional changes in Chapter 4, where attention is drawn chiefly to the influence of man through his use of fire and the application of grazing pressure by domestic livestock. Chapter 5 discusses the genera used to typify the main zones, with notes on their distribution. The bulk of the publication is occupied by Chapter 6 which lists the main grasses and associated woody species for each of the 174 communities recognized. It may be noted that the physiognomic demarcations are similar to, but by no means identical with, those shown on the map of the same scale produced by A.E.T.F.A.T. (Oxford University Press) in 1959, charting the vegetation of Africa (south of the Tropic of Cancer). The FAO map under review shows, in addition, the interesting interactions between the main species of the grass cover and the associated woody plants. It is significant that the boundaries of the grass and woody communities do not always coincide and it is the general experience of field workers, at least in southern Africa, that a vegetation based on physiognomy alone does not meet the requirements of those engaged in the utilization of the herbage cover. There is undoubtedly room for recording both types of information, as has been done on this map. The map is produced on good quality paper and the colours and hatchings are well chosen, resulting in a pleasing effect. The text is up-to-date in nomenclature while a good standard of editing has been maintained, so that very few typographical errors were observed. An adequate bibliography is appended in which the only important omission noted is the excellent account, with accompanying map, of the vegetation of Mocambique by J. G. Pedro and L. A. G. Barbosa in Vol. 11 of "Esboco do reconhecimento ecologica-agricola de Mocambique" published in 1955 by Imprensa Naçional de Moçambique, Lourenço Marques. It is also not clear whether the estimates of carrying capacity given in the text are based on published information and, if so, where this can be found.—L. E. CODD. From *Herbage Abstracts*.

RUSSELL, E. W. **Soil conditions and plant growth.** 9th Edition 1961. Pp xvi + 688 + 38 plates. Longmans, Green and Co. Ltd., London, 63*s.*

To those who farm the land, to those who experiment in agriculture and particularly to those who, in ever increasing numbers, have the temerity and foresight to do both, I would recommend the companionship of of this book. Farming is fast becoming a specialized section of a close-knit agricultural industry. It is that section which primarily uses land as an agent of production. The efficient use of land requires an understanding of the soil, both in general and particular. Moreover, the effective incorporation into an evolving system of farming of the new techniques, the new machinery and fertilizers and chemical agents made available by other sections of this industry demands some conception of processes and mechanisms—in

particular those processes and mechanisms which operate between crops and the soils on which they grow and find expression in yield. Reference to a relevant part of this comprehensive work will invariably provide information on what is involved in a particular relationship between plant and soil. And, as with all good works of reference, the reader will be tempted to read beyond the limits of the original question. The first edition of Soil Conditions and Plant Growth by Sir E. John Russell, published in 1912, set a course which has been followed closely by this, the ninth, edition: to eschew opinion and to present a summary of knowledge that the reader's own judgement be improved. The factual nature of this book is expressed both in the text and in 194 tables and figures. Copious references to literature, given as footnotes to each page, are supplemented by an author index. That the contents deal far more with details of the soil than with growth of plants is a fault not so much of the author, but of the way in which research into soil problems has been conducted, with scant reference to the physiology of crops. It is a pity that the study of plants and soil is so often divorced when the union could be so fruitful. A more serious criticism is that some of the information is not up-to-date. Only a little arithmetic is probably required to bring the quantities of nutrients removed from an area of soil by different crops, given in table 122, into line with present day yields. Why present values relevant to yields common in 1886?—C. R. CLEMENT. From *Field Crop Abstracts*.

ABSTRACT

DE BOER, F. AND WILLEMSEN, W. [**Factors for calculating stocking rate in terms of cattle units.**] *LandbVoorl.* 1960, **17**, No. 7, 326–8.

The average daily requirements in starch equivalent of calves, milking cows, bulls, store cattle, horses, foals and sheep have been used to calculate conversion factors (given) for the adjustment of stocking rate to dairy-cow equivalents. These factors are considered important when determining the herbage yield from grazing land.—R.B. From *Herbage Abstracts*.